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# Sovereign Spreads and Unconventional Monetary Policy in the Euro Area: A Tale of Three Shocks\*

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## Abstract

High-frequency (HF) monetary surprises around central bank meetings are extensively employed to jointly identify monetary policy shocks and the so-called ‘information shock’. In this paper we show that HF surprises in the Euro Area after 2008 reflect the impact of three shocks, not two. Besides an unconventional monetary shock and the information shock, we consider a third shock, labelled ‘spread shock’, resulting from the ECB management of fragmentation risk in the sovereign bond market. The spread shock can be framed within a stylized model of multiple equilibria where a central bank in a monetary union attempts to offset self-fulfilling expectations of default in sovereign debts. We point-identify simultaneously the dynamic causal effects produced by the three monetary policy shocks by using a proxy-SVAR estimated on daily data. The external instruments are obtained from HF monetary surprises combining sign and narrative restrictions, and additional point restrictions are exploited for the identification in a second stage. Empirical results based on Italian (Spanish) spreads, reveal that the spread shock represents an important ingredient of the transmission mechanism of monetary policy in the Euro Area after the Global Financial Crisis. Identification-robust confidence intervals show that the impact of the spread shock on monthly variables like industrial production and measures of systemic risk and financial distress is non-negligible and aligns with the idea that the ECB stabilizes fragmentation risk.

**Keywords:** European Central Bank, Monetary Policy Shock, Proxy-SVAR, Spread Shock

**JEL codes:** E43, E44, E52, E58, G10, C32

# 1 Introduction

Since Kuttner (2001) to most recent studies, high-frequency (HF) variations in asset prices and interest rates around relevant monetary policy events have been largely employed to identify the effects of policy surprises on macroeconomic variables; see among others, Gürkaynak *et al.* (2005), Cochrane and Piazzesi (2002), Hamilton (2008), Campbell *et al.* (2012), Gertler and Karadi (2015), Altavilla *et al.* (2019) and Cesa-Bianchi *et al.* (2020). The assumption at the basis of HF identification methods is that surprises in the narrow window around monetary policy announcements reflect only unanticipated monetary shocks. However, recent studies have shown that HF variations of asset prices and interest rates give rise to unexpected puzzling comovements which suggest that other forces, different from ‘pure’ monetary policy shocks, might be embedded in these variations; see, among others, Nakamura and Steinsson (2018), Cieslak and Schrimpf (2019), Jarocinski and Karadi (2020), Andrade and Ferroni (2021), Hoesch *et al.* (2020), Miranda-Agrippino and Ricco (2021) and Cesa-Bianchi *et al.* (2020).<sup>1</sup> The most accredited explanation is that of a ‘central bank information effect’ or a ‘signalling channel’, namely an additional component in HF variations also transmitted to the economy. Central banks have high-quality information about the future state of the economy which is disclosed during announcements, affecting market expectations. This may generate puzzling comovements between yields and stock prices because, e.g., a release of positive information may simultaneously drive up expectations about future economic growth, stock prices and interest rates.<sup>2</sup> The issue becomes particularly relevant in the identification of unconventional monetary policy shocks which typically affect the yield curve at medium-to-long maturities. Long term rates incorporate expectations of market participants and tend to reflect the information effect.

In this paper we focus on the Euro Area and on HF surprises in interest rates and asset prices observed around press conferences held by the ECB. As is known, monetary policy in the Euro

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<sup>1</sup>A contractionary monetary shock should generate a negative comovement, i.e. an increase in interest rates and a decrease in stock prices (Bernanke and Kuttner, 2005). Actually, Jarocinski and Karadi (2020) show that for almost 40% of monetary events in the Euro Area a positive comovement between the 3-month interest rate and the stock market index is observed.

<sup>2</sup>This view is not universally shared in the literature. We refer e.g. to Bauer and Swanson (2021) and references therein for an alternative interpretation.

Area is complicated by the fact that there are 19 sovereign bond markets which make fragmentation risk a concern. Assuming that the ECB takes this risk into account and plays an active role in the management of expectations on sovereign debt crises, see e.g. Lane (2021), we include sovereign spreads of peripheral countries among the relevant HF monetary surprises observed in the narrow windows during which policies are announced and discussed.<sup>3</sup> Doing so, we observe puzzling correlations between HF variations of risk premia on Italian (and Spanish) bonds and risk-free rates at different maturities that the ‘two-shocks’ paradigm (monetary/information) cannot fully explain. Indeed, while one would expect positive correlations between these variations, the data reveal periods of negative correlations that tend to cluster around debt crisis episodes. An unconventional monetary shock such as the one resulting from forward guidance (FG) or quantitative easing (QE) policies should reduce (increase) medium/long term rates and reduce (increase) risk premia on risky sovereign bonds; see e.g. Altavilla *et al.* (2021) for an example in which QE shocks affect credit risk of peripheral bonds.

Based on these evidences, we argue that HF monetary surprises in the Euro Area reflect a combination of three, not two shocks. The attempt of the ECB to eliminate self-fulfilling expectations of defaults in the sovereign debt market motivates the identification of a ‘third shock’, i.e. a risk premium shock that we conventionally label *spread shock*. The spread shock arises from the central bank’s announcements that, in correspondence of particular periods or episodes, affect expectations about a break-up of the Euro Area as measured by credit/redenomination risk premia.

The spread shock complements the monetary policy shock and a ‘pure’ information shock reflecting the idea that, broadly speaking, a ‘monetary policy shock’ in the Euro Area reads as a multidimensional and multifaceted object whose transmission does not necessarily exhaust into

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<sup>3</sup>Since the famous ‘whatever it takes’ speech by Mario Draghi on July 26, 2012, market participants metabolized the active role the ECB plays in keeping expectations about the breakup of the Euro Area and redenomination of peripheral debts into local currencies under control (De Grauwe, 2012). Moreover, in the press conference held on March 12, 2020 in the aftermath of the Covid-19 pandemic outbreak, the Governor Christine Lagarde stated: ‘*we don’t close spreads*’, referring to the responsibility of the ECB to compress sovereign risk premia. The sharp reaction of financial markets signalled that expectations were quite the opposite. This event further revealed the active role the ECB plays in stabilizing fragmentation risk.

the categories of ‘conventional’ and ‘unconventional’. The spread shock is characterized by two important, interrelated features that make its identification challenging: (i) the ECB cannot directly target specific countries interest rates, hence its desire to stabilize fragmentation risk is paired with an undefined instrument which complicates the communication of its transmission; (ii) a spread shock is inherently and qualitatively similar to an information shock. Keeping these limits and difficulties in mind, in this paper we recognize that (i) is an open question and take a stand on (ii). Our analysis is driven by two main ideas. One is that anti-fragmentation risk policies are of increasing importance in the Euro Area and it is therefore important to attempt to quantify the dynamic causal effects produced by a spread shock on variables of interest, especially in the presence of changing scenarios about the economic outlook.<sup>4</sup> The second is that, despite its qualitative similarity to the information shock, on the quantitative side the observed movements of sovereign spread surprises relative to interest rate and stock price surprises are sometimes smaller and sometimes, during debt crisis, larger, which suggests that a single information shock does not suffice to capture these comovement well. Our view is that the spread shock is characterized by distinguishing features that can be picked out from HF monetary surprises and exploited empirically: (a) it tends to cluster around debt crisis periods; (b) its impact on sovereign spreads is relatively higher than the impact of the information shock on sovereign spreads; (c) its instantaneous (and lagged) impact on the economic outlook is different from the instantaneous (and lagged) impact exerted by the information shock. In support of our arguments, and as in Motto and Özen (2022), we find it implausible that certain episodes such as e.g. the Outright Monetary Transaction (OMT) announcements can be thought of as being driven by a ‘pure’ signalling effect. Thus, despite the above mentioned difficulties, the empirical

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<sup>4</sup>On June 28, in her speech at the ECB Forum on Central Banking 2022 on ‘Challenges for monetary policy in a rapidly changing world’ in Sintra, Portugal, Christine Lagarde, President of the ECB observes that *The normalization of our monetary policy will naturally lead to rising risk-free rates and sovereign yields. And, as euro area sovereigns are starting from different fiscal positions, it can also lead to a rise in spreads. But in order to preserve the orderly transmission of our policy stance throughout the euro area, we need to ensure that this repricing is not exacerbated and distorted by destabilizing market dynamics, leading to a fragmentation of our original policy impulse. That risk of fragmentation is also affected by the pandemic, which has left lasting vulnerabilities in the euro area economy. These vulnerabilities are now contributing to the uneven transmission of the normalization of our policy across jurisdictions.*

simultaneous identification of both shocks can contribute to improve our understanding of their economic consequences.

Independently from our work, Motto and Özen (2022) identify a ‘market-stabilization QE’ shock which resembles the features of the risk-premium shock we originally introduced in the working paper version of this article, see Fanelli and Marsi (2021), and that we further elaborate and expand here. A detailed analysis of the analogies and differences between our approach and Motto and Özen’s (2022) approach is postponed to Section 2.

From a theoretical point of view, we justify the role of a spread-type shock by considering a stylized model of multiple equilibria where, along the lines of De Grauwe and Ji (2013), a central bank in a monetary union affects agents’ expectations to stabilize fragmentation risk. Given its policy reaction function, the central bank also manages yield spreads to shift expectations about the probability of default of a given country from an equilibrium in which the default can be beneficial to the country to an equilibrium in which the cost of defaulting overcomes the benefit. This stylized model predicts that the central bank response to a contractionary demand shock triggering the probability of default of peripheral countries induces: (p1) a decrease in the sovereign risk premium; (p2) an increase of the risk-free interest rate; (p3) an increase of real economic activity. We recognize that from a purely theoretical perspective, the predictions (p1)-(p2)-(p3) do not suffice to separately identify a spread shock from an information shock. To separately identify these two shocks we endow the reference theoretical model with the empirical facts (a), (b) and (c) stated above. This is one of the main contributions of our paper.

We trace out the dynamic causal effects produced by the three shocks by a two-steps approach. In the first-step, we use the Euro Area monetary policy event-study database (EA-MPD) built by Altavilla *et al.* (2019) to approximate HF surprises in interest rates, spreads and the stock market by three factors which are statistically not rejected by formal tests. By combining sign restrictions with other type of narrative/institutional/magnitude restrictions, we set-identify the three factors and interpret them as an unconventional monetary policy factor, an information factor and a spread factor, respectively.<sup>5</sup> (In this step we use the word ‘factor’

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<sup>5</sup>We refer to e.g. Swanson (2021), Antolín-Díaz and Rubio-Ramírez (2018), Furlanetto *et al.* (2019), Ludvigson *et al.* (2021) and Caggiano *et al.* (2021) for the role of narrative/institutional restrictions in structural shocks identification.

and not ‘shock’ because the factors are used as external instruments for three structural shocks in a second-step). In this first-step, the spread factor is isolated from the information factor via two conditions: the variance of the spread factor during periods of high stress on sovereign debts is assumed larger than it is in other periods; the magnitude of the loadings associated with the spread factor on the spread curve of peripheral countries is assumed larger (in absolute value) than the magnitude of the corresponding loadings associated with the information factor.

In the second-step, we select three ‘representative’ factors from the set identified in the previous step and use them as external instruments in a (point-)identified proxy-SVAR estimated on daily data. As is known, proxy-SVARs that feature multiple target shocks require additional (point- or sign-) restrictions for identification; see e.g. Angelini and Fanelli (2019) and Giacomini *et al.* (2022). We (point-)identify our proxy-SVAR by imposing a number of zero restrictions that imply an overidentified, testable model. The testable overidentification restriction ensures that the identified spread shock does not contain ‘pure’ information components. In this second-step we simultaneously (point-)identify the dynamic causal effects produced by an (*unconventional*) *monetary policy shock*, an *information shock* and our *spread shock* on target financial variables such as the stock market index, the 2-year Euro Area inflation-linked swap rate and the EUR-USD nominal exchange rate. We find that the estimated overidentified proxy-SVAR is not rejected by the data.

In our baseline empirical specification, sovereign spreads refer to Italy, the most important peripheral country in the Euro Area in terms of economic size and dimension of sovereign debt. However, we check the robustness of our results to considering Spain as leading peripheral country. Moreover, we also check the robustness of our results to considering HF surprises observed around both press conferences and press releases from 2016.

Empirical results on the period from January 2002 to June 2020 can be summarized as follows. The introduction of the spread shock improves the identification of the unconventional monetary shock, as the latter generates a positive comovement between the risk-free yield curve and sovereign spreads along the lines of Altavilla *et al.* (2021). A reduction in sovereign spreads due to an expansionary spread shock policy increases the risk-free yield curve for approximately 6-months, with a persistent effect. The expansionary spread shock is accompanied by an increase



in stock market prices, an appreciation of the EUR-USD exchange rate and an effect on the 2-year Euro Area inflation-linked swap rate. Importantly, the spread shock does not seem to dramatically undermine the role of a ‘pure’ information shock suggesting that the central bank signalling channel remains effective. In this respect, the spread shock provides an explanation of the wrong-signed comovement observed between stock prices and interest rates complementary to that outlined in Jarocinski and Karadi (2020).

Next, we investigate whether it is possible to retrieve the effect of the spread shock on Euro Area target variables at the business cycle frequency. In particular, we focus on monthly time series of industrial production, consumer prices and measures of systemic risk and financial distress. Since most of these variables are available only at the monthly frequency, we aggregate part of the variables and the proxies used for the daily proxy-SVAR. We quantify the impact of the spread shock on monthly variables of interest by a local projection instrumental variable (LP-IV) approach à la Stock and Watson (2018). More precisely, in order to robustify the inference against non-invertibility issues and the possible loss of strength of the instrument induced by the data aggregation process, we rely on identification-robust Anderson and Rubin (AR) confidence sets (Andrews *et al.*, 2019). Our empirical findings for Italy (Spain) show that the spread shock tends to stabilize economic fluctuations and aligns with the prediction of our theoretical stylized model: an expansionary spread shock has a non-negligible impact on real economic activity (but a less clear-cut one on prices), triggers a positive reaction in stock prices and smooths agents’ perception of systemic risk and financial distress.

On the policy side, the suggested ‘three-shocks’ paradigm (monetary/information/spread) improves our understanding of the Pandemic Emergency Purchase Program (PEPP) launched by the ECB in 2020 to contrast the COVID-19 pandemic outbreak. The PEPP is a QE program which entails a major difference with respect to the previous QE launched by the ECB in 2015, the Asset Purchase Program (APP). The goal of the APP was to intentionally affect the common component of long term sovereign rates and, for this reason, purchases of sovereign bonds were split across Euro Area countries according to a fixed rule based on the economic size of each country: the rationale was not to favor some countries over others. Instead, the PEPP has been designed in a more flexible way, giving priority to countries under stress. As explained

by Lane (2021), the PEPP entails a dual objective: keeping the risk-free yield curve low while managing fragmentation risk. Looked with the lens of our three-shocks decomposition, HF monetary surprises associated with PEPP-related announcements embody both unconventional and spread-type shocks, hence our methodology allows to evaluate the efficacy of such a dual-objective policy.<sup>6</sup>

**Organization.** The rest of the paper is organized as follows. Section 2 explains how our contribution is related to the extant literature on HF identification of monetary policy shocks. Section 3 introduces the empirical puzzle that motivates the paper. Section 4 frames the spread shock within a stylized theoretical model where a central bank attempts to offset self-fulfilling expectations of sovereign debt default. Sections 5 and 6 describe the methodology and present the empirical results obtained from a proxy-SVAR estimated on daily data. Section 7 retrieves the effects of the spread shock on monthly target variables through identification-robust LP-IVs. Section 8 contains some concluding remarks.

The Appendix formalizes the theoretical model (Appendix A.1) and provides further empirical evidence in support of a spread factor characterizing HF surprises in the Euro Area (Appendix A.2). An online Supplementary Material complements the paper along several dimensions, including some econometric details of our approach and a number of robustness checks which are mentioned in the paper.

## 2 Connections with the literature

The use of HF methods to identify monetary policy shocks dates back to Kuttner (2001) and Cochrane and Piazzesi (2002). The seminal work of Gürkaynak *et al.* (2005) suggested to use factor (principal components) analysis to extract time-series from a bunch of yields variations interpretable as monetary policy factors. Recently, a fast developing literature has focused on the identification of multiple shocks around monetary policy events. Nakamura and Steinsson (2018) and Miranda-Agrippino and Ricco (2021) consider US data, Cesa-Bianchi *et al.* (2020)

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<sup>6</sup>Purchases under the PEPP program ended in March 2022. As one could expect, the announcement of the end of PEPP, made on December 16, 2021, caused a sharp increase in the sovereign spread of Italian bonds.

the UK and Jarocinski and Karadi (2020) and Andrade and Ferroni (2021) analyze the Euro Area. Jarocinski and Karadi (2020) and Andrade and Ferroni (2021) exploit sign restrictions to disentangle information shocks from monetary policy shocks embedded in HF responses of the stock market and inflation expectations, respectively. In the first-step of our empirical identification exercise we partially rely on their methods.

A recent contribution strictly related to ours is Motto and Özen (2022). These authors also recognize that surprises extracted from risk-free interest rates do not generally suffice to characterize the ‘multiple dimensions’ feature of monetary policy in the Euro Area. Similarly to us but independently from us, Motto and Özen (2022) pursue a two-step approach on comparable sample periods. In the first-step, they extend the approach in Altavilla *et al.* (2019) to identify an additional factor extracted from Euro Area HF monetary surprises that include sovereign spreads. They also identify a novel factor by resorting to the idea that risk-free rates and sovereign spreads move in the same direction in response to what they call a transmission shock. They motivate the negative correlation with a ‘flight-to-quality dynamics’ argument, while we take it from the stylized model sketched in Appendix A. The identified factor is used in a second-step as an external instrument in a daily (Bayesian) proxy-SVAR to examine the channels through which market-stabilization QE affects sovereign yields across Euro Area countries. Motto and Özen (2022) include Italian and Spanish spreads simultaneously in their daily proxy-SVAR and follow a standard ‘one shock-one instrument’ approach. Conversely, our baseline daily proxy-SVAR employs three external instruments to identify three shocks simultaneously and is specified considering Italy as representative peripheral country. We check ex-post the robustness of results when Italy is replaced with Spain. Despite these non-negligible methodological differences, the empirical results in Motto and Özen (2022) do not depart too far from ours, in the sense that the dynamic causal effects of their market-stabilization QE shock are largely consistent with the dynamic causal effects we document for our spread shock.

Similarly to us but following a different route, Motto and Özen (2022) also provide an assessment of the macroeconomic relevance of the market-stabilization QE shock on monthly variables. They rely on a two-country-block VAR model which jointly includes periphery (an average measure of Italy and Spain) and core (an average measure of Germany and France)

countries, respectively. The market-stabilization QE factor is aggregated at the monthly frequency and used as external instrument in the two-country-block model. Empirical results in Motto and Özen (2022) tend to align with the findings we obtain with our identification robust LP-IVs; for instance, they also report an important effect on industrial production. On the contrary, their effect on monthly inflation is not transparent from our estimates. Again, despite the methodological differences in the two approaches, our results appear to complement those in Motto and Özen (2022) and vice versa. Both contributions clearly point out the importance that the spread/transmission shock exerts on the Euro Area business cycle.

Our paper is also related to Leombroni *et al.* (2021) who, adopting a core/periphery perspective, focus on the effects of ECB communication of the sovereign yields in the Euro Area. They identify two shocks from HF surprises observed around press conferences: an interest rate shock and a risk premium shock. The interest rate shock captures surprises that reflect FG and information effects from communication and announcements by the ECB about the future path of the short term rate. This shock is identified by principal component analysis considering variations in the OIS rates along the yield curve. The risk premium shock is meant to capture policies by the ECB that affect directly the risk premium and credit risk of peripheral countries. This second shock is identified by taking the variations in the stock market index which are orthogonal to the interest rate shock. Our analysis differs from Leombroni *et al.* (2021) in two important dimensions. First, the interest rate shock in Leombroni *et al.* (2021) conveys both the information and monetary effect, as they do not exploit the comovements of OIS rates and stock prices to isolate the two components. Second, we identify our spread shock (the analogue of their risk premium shock) using a different empirical identification strategy, which requires taking a stand on the expected comovement between OIS rates and sovereign spreads.

Cieslak and Schrimpf (2019) have a direct contact with our analysis in the sense that they also assume that three types of structural shocks affect HF surprises of interest rates around monetary policy announcements: a monetary shock, an information shock and a risk premium shock, where the latter is tied to news that impact on the price of risk in financial markets. These authors exploit sign restrictions on HF comovements of the yield curve and stock prices. Similarly to Cieslak and Schrimpf (2019), we also identify a risk shock - our spread shock - yet

with an important difference. While Cieslak and Schrimpf (2019) interpret their third shock as the realization of ‘flight-to-safety’ episodes which move the yield of safe government bonds downwards, we are more specifically interested to the risk premium on the sovereign bonds of Euro Area peripheral countries and to do so we exploit the idea that the third structural shock affects the Euro Area risk-free yield curve through expectations.

A recent literature estimates the effects of unconventional monetary policies in the Euro Area. Prominent examples (that do not exhaust the list) are e.g. Rogers *et al.* (2014), Altavilla *et al.* (2021), Altavilla *et al.* (2016), Gambetti and Musso (2020), Krishnamurthy *et al.* (2018) and Dewachter *et al.* (2016). These studies devote attention to specific types of unconventional measures in isolation while we provide a comprehensive estimate of monetary policy shocks that act simultaneously over the whole lifetime of the Euro Area. Inspired by the studies in Gürkaynak *et al.* (2005) and Swanson (2021) that refer to the US, Altavilla *et al.* (2019) extract factors from HF variations of the risk-free yield curve around ECB meetings. We use Altavilla *et al.* (2019)’s EA-MPD database to build the external instrument used to simultaneously identify our three monetary shocks.

In a comment of the work by Altavilla *et al.* (2019), Wright (2019) remarks the need to consider also HF variations in sovereign spreads to fully characterize the policies put forth by the ECB and construct a ‘save-the-Euro-factor’ which resembles our spread shock; see also Motto and Özen (2022). We differ from Wright (2019) along two main dimensions. First, we do not dismiss the importance of the information shock which is identified jointly with the monetary shock and the spread shock. Second, we show that the ‘save-the-Euro-factor’ is indeed embedded in HF variations of the risk-free yield curve; see e.g. Altavilla *et al.* (2019).

Our paper is also related to Hachula *et al.* (2020), who solve the issue of disentangling different types of monetary policy shocks in the Euro Area through an identification strategy that splits the estimation sample into two parts: a ‘phase 1’ period (2007-2014) for which they assume the ECB targets periphery spreads, and a ‘phase 2’ period (2014-2016) for which they maintain the ECB targets the risk-free yield curve. Our approach accounts for the multidimensional aspects of monetary policy in the Euro Area without the need to split the estimation sample *a-priori*.

On the methodological side, our paper contributes to the fast growing literature that exploits

information from external variables to identify dynamic causal effects in proxy-SVARs (SVARs-IV) in which multiple instruments are used to identify multiple target shocks. In these cases, additional (point- or sign-) restrictions must complement the instruments, see e.g. Mertens and Ravn (2013), Mertens and Montiel Olea (2018), Lakdawala (2019), Angelini and Fanelli (2019) and Giacomini *et al.* (2022). To our knowledge, ours is the first contribution in the monetary policy context where three structural shocks are (point-)identified simultaneously in a proxy-SVAR. When dealing with monthly variables obtained by averaging daily counterparts, we robustify our inference based on LP-IVs against two main issues that might arise: the potential weakness of the proxy used for the spread shock and the possible noninvertibility of the latter. In this respect, our modelling approach shares similarities with Alessandri *et al.* (2021) but also differences.

### 3 The OIS-spread puzzle and policy surprises: some preliminary evidence

In this section we present some *prima facie* empirical evidence that motivates a spread shock in the Euro Area. In particular, we document a puzzle that arises from the investigation of the dynamics of HF monetary surprises observed around the press conferences regularly held by the ECB.

As detailed in e.g. Altavilla *et al.* (2019), monetary policy decisions in the Euro Area are announced in two separate steps. First, decisions related to policy rates are made public in the press release. Later, a press conference is held by the ECB president. In this occasion, unconventional policies are announced and policy measures are discussed. This two-steps announcement procedure can be exploited to disentangle HF surprises of interest rates and asset prices into different components associated with different aspects of the policies pursued by the ECB. Throughout the paper, we use the EA-MPD dataset constructed by Altavilla *et al.* (2019) and, as our interest is on unconventional policies only, we focus on HF surprises observed around press conferences alone. This strategy allows us to disregard movements reflecting short term policy-rate decisions which are confined to press releases.<sup>7</sup> Our main focus is on Overnight

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<sup>7</sup>From 2016 the announcements of unconventional policies are also contained in the press releases. In the

Indexed Swap (OIS) rates and to better characterize unconventional policies, we observe HF surprises at several maturities of the term structure of OIS rates. Several contributions discuss how conventional and unconventional monetary shocks affect risk-free rates along the term structure; see Gürkaynak *et al.* (2005), Hanson and Stein (2015) and Altavilla *et al.* (2019), among many others.

A monetary shock, being it conventional or unconventional, should generate a negative comovement of risk-free yields and stock prices (Bernanke and Kuttner, 2005). Indeed, an unexpected increase in interest rates depresses future economic activity and then causes a downward revision of stock prices. However, as explained by Jarocinski and Karadi (2020), more than 40% of the HF changes of the 3-months OIS rates and the STOXX50 index around ECB announcement days display a wrong-sign comovement, i.e. positive rather than negative signs. Jarocinski and Karadi (2020) focus on HF surprises around both press releases and press conferences for each relevant day, and sum these two variations. They entirely ascribe the observed puzzling comovements to the information effect. Figure 1 displays how the fraction of wrong-signed events associated with ECB announcements changed in the last 15 years.<sup>8</sup> It is seen that the fraction of wrong-signed events tends to be higher at the beginning and at the end of the sample period with peaks concentrated during debt crisis times, or episodes of financial and fiscal stress. This preliminary evidence suggests that the prevalence of wrong-signed events could be related as well to the role played by the ECB in managing sovereign debt crisis and not solely to a ‘pure’ information/signalling effect.

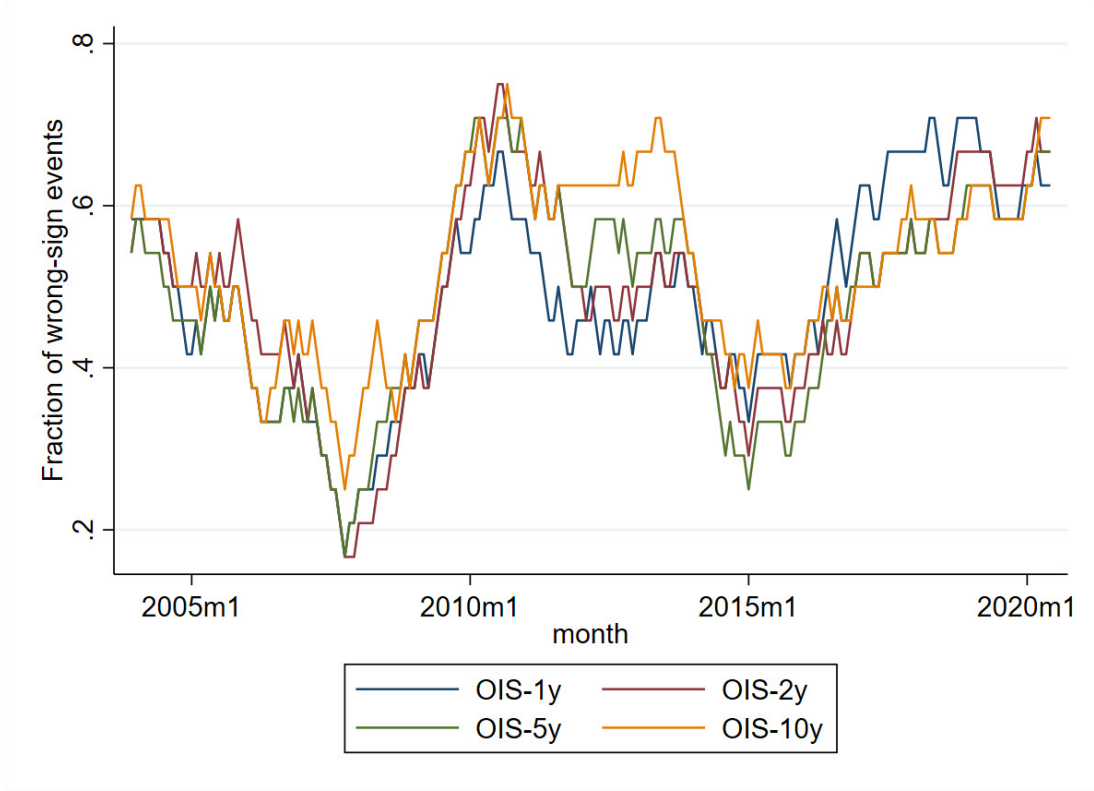
To proceed, we enlarge the information set including sovereign spreads into the picture. 

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Supplementary Material we conduct a robustness check by changing the relevant announcement window from 2016 onward.

<sup>8</sup>The fractions in the graph have been computed through a 2-years rolling window analysis. More precisely, consider all dates in which the ECB held press conferences in the period 2002-2020. For each of these dates, indexed by  $d$ , let  $\Delta^{hf}OIS_{d,m}$ ,  $m = 1, 2, 5, 10$  (years) denote HF variations in the OIS rates at different maturities, and let  $\Delta^{hf}STOXX50_d$  be the HF variations in the STOXX50 index. With the symbol ‘ $(\Delta^{hf}x, \Delta^{hf}z)_+$ ’ we indicate that the variables  $x$  and  $z$  vary in the same direction and with ‘ $(\Delta^{hf}x, \Delta^{hf}z)_-$ ’ that vary in opposite directions. The plots in Figure 1 correspond to the fractions

$$f_{d,m} = \frac{\# \text{ of episodes in the last two years in which } (\Delta^{hf}OIS_{d,m}, \Delta^{hf}STOXX50_d)_+}{\# \text{ total episodes in the last two years}}.$$



**Figure 1:** Fractions of press conferences held by the ECB that display ‘wrong-signed’ comovements between OIS rates at different maturities and the STOXX50 index, computed through a 24-months rolling window, see footnote 8 for details. The horizontal axis reports the last month of the window.

While a negative comovement between OIS rates and the stock index is expected, we would also expect positive comovements between OIS rates and sovereign spreads if monetary shocks were the only driving forces in the considered windows. Note that in this paper we refer to ‘unconventional monetary shock’ as a broad category encompassing shocks due to e.g. FG or QE. An unconventional monetary shock, which affects long term risk free rates, should generate a positive comovement between OIS rates and Euro Area periphery risk premia around ECB press conferences.<sup>9</sup> Let us consider a FG shock arising from the ECB announcing an unexpected decline in the future path of short term interest rates. This causes a drop in medium-to-long term rates which stimulates the economy and increases stock prices and, arguably, also reduces periphery risk premia. This final effect, should therefore relieve pressures on high sovereign

<sup>9</sup>We will refer to OIS rates as the risk-free rates though this definition is not completely appropriate. Indeed long term OIS rates command a risk premium since they incorporate some duration risk. Nonetheless, these rates are risk-free in the sense that they do not carry any default/redenomination risk premium.



debts. Similarly, as shown by Altavilla *et al.* (2021), QE reduces the price of risk for both long-term risk-free yields and risky peripheral sovereign debt through the portfolio-rebalancing channel.<sup>10</sup>

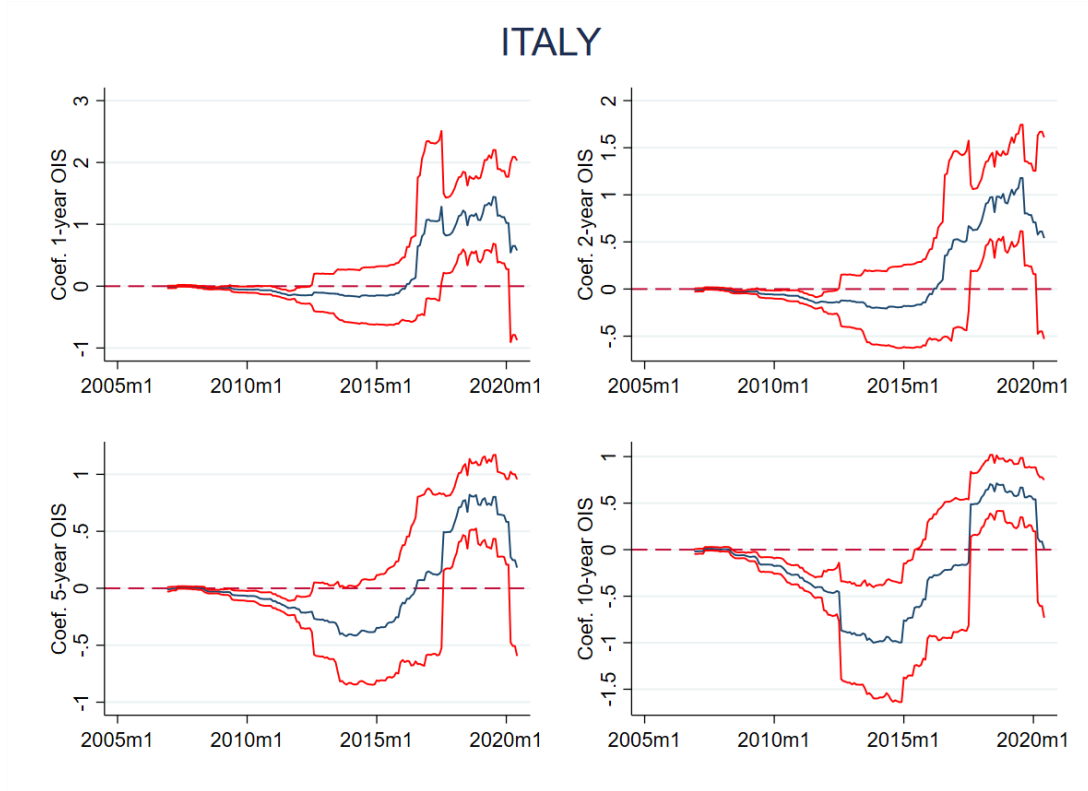
Compared to the US and other major economies, the Euro Area is characterized by a fragmented sovereign debt market where each sovereign debt can be associated with a different credit (or redenomination) risk. During the debt crisis started after the Great Recession of 2008, debt issues have become enormously relevant. To contain the spreads of peripheral countries the ECB had to manage the perceived risk about a break-up of the Euro Area. Starting from the famous ‘*whatever it takes*’ speech by Mario Draghi on July 26, 2012, the ECB was able to restore confidence in the solidity of the monetary union and improve the convergence of sovereign rates around the Euro Area. This goal has been reached through an accommodating communication strategy and unconventional measures such as the OMT, the LTRO and the QE.

Figure 2 plots the coefficients obtained from 5-year rolling window regressions of HF variations around ECB press conferences of a measure of the risk premium on Italian bonds as captured by the spread between 10-year Italian and OIS rates on HF variations of OIS rates from 1-year to 10-years maturity. These regressions are carried out on the whole lifetime of the Euro Area. Figure 3 plots regression coefficients of analogue regressions obtained considering the risk premium on Spanish bonds. A clear pattern emerges from these graphs. In the initial period until 2010, regression coefficients are zero as sovereign spreads were very low and not varying at all. During the debt crisis period regression coefficients turn out to be negative and become significant when using the 10-year OIS rates as regressor. When considering the QE period from 2014/2015, the estimated regression coefficients become positive and significant. The change of signs in the correlations over time suggests that the monetary shocks that generate a positive correlation between risk premia and risk-free rates have been prevailing in the QE period, while other mechanisms have been predominant during the debt crises. The information shock does not suffice alone to explain the marked changes occurred over the whole lifetime of

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<sup>10</sup>Furthermore, policies like Long Term Refinancing Operations (LTROs) are aimed at increasing the supply of long term loans by banks, thus reducing long term risk free rates. These liquidity injections have been used by commercial banks also to increase their exposure to risky sovereign debt (Crosignani *et al.*, 2020), again leading to a reduction in sovereign spreads.

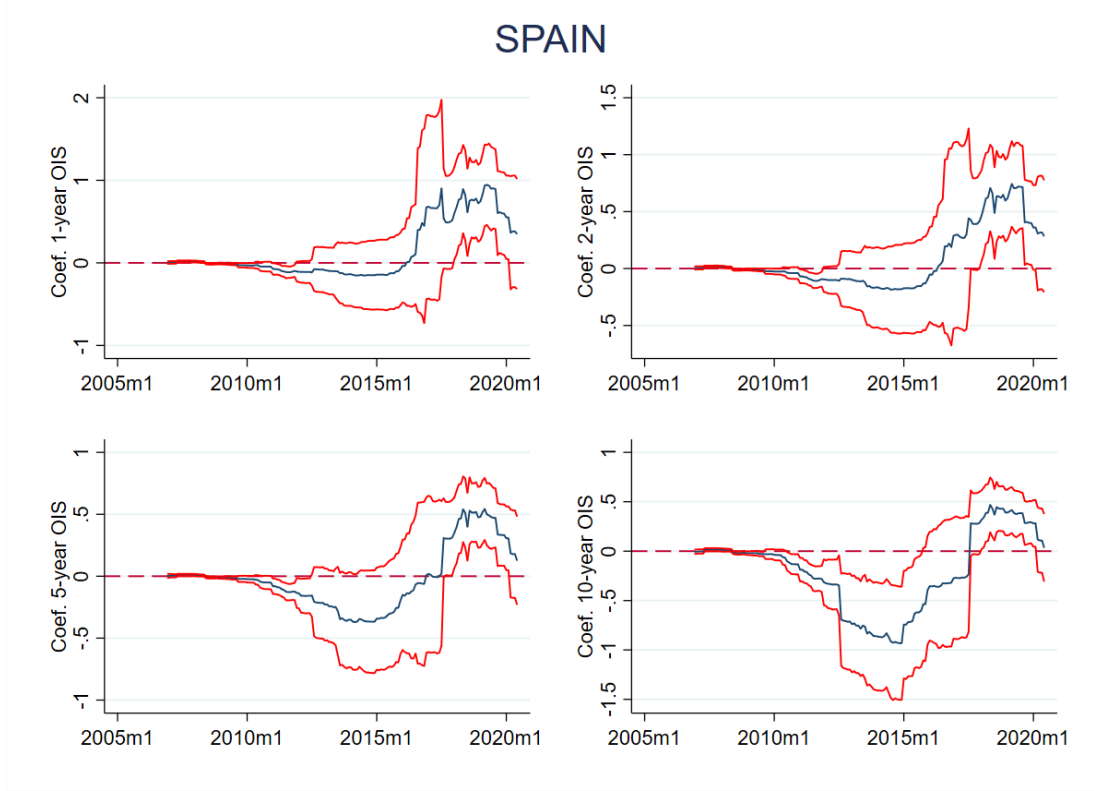
the Euro Area. We argue that these changes can be ascribed to the role that the ECB plays in influencing expectations about the break-up of the Euro Area, redenomination of peripheral debt and sovereign defaults.



**Figure 2:** 60-months rolling window estimates (blue lines) of the regression coefficients obtained by regressing HF surprises in the 10-year IT-OIS (Italy) on HF surprises on OIS rates around ECB press conferences. Red lines are 95% confidence intervals. The horizontal axis reports the last month of the window.

## 4 Managing fragmentation risk: the spread shock

Modelling fragmentation risk in the Euro Area through a policy rule that mirrors ‘traditional’ monetary policy rules and accounts for the multifaceted dimension of monetary policy is a difficult task that we do not pursue here. The ECB cannot directly target specific countries interest rates, hence it intentionally keeps some level of uncertainty and discretionality about the role it plays in stabilizing this risk. Most likely, the ECB follows this strategy also to avoid inducing moral hazard behaviours by highly indebted sovereign countries. These facts complicate the issue of separately identifying a risk premium shock from the information channel. Keeping



**Figure 3:** 60-months rolling window estimates (blue lines) of the regression coefficients obtained by regressing HF surprises in the 10-year ES-OIS (Spain) on HF surprises on OIS rates around ECB press conferences. Red lines are 95% confidence intervals. The horizontal axis reports the last month of the window.

these difficulties in mind, in this section we refer to a broad, stylized theoretical framework and ascribe to narrative/institutional Euro Area features the task of providing the additional information necessary to empirically disentangle the effects produced by the spread shock from the effects of other monetary/information shocks.

Building on a slightly modified version of the multiple equilibria model considered in De Grauwe and Ji (2013), we justify the role of the spread shock by considering a stylized theoretical model in which a central bank that faces fragmentation risk in a monetary union attempts to stabilize the economy by affecting expectations about sovereign defaults.<sup>11</sup> The

<sup>11</sup>The shift in expectations about default of peripheral countries can potentially be achieved in several ways. For instance, in Darracq Pariès *et al.* (2020) there exists a second monetary policy rule by which the ECB adjusts its purchases of risky debt to respond to changes in risk-premia. A second monetary policy rule is also featured in Sims *et al.* (2021), though the purpose of this rule is to manage credit risk originating from capital constraints on financial intermediaries.

model, whose details may be found in Appendix A.1, features an IS-LM-type equilibrium with fixed prices, but can be extended to a staggering prices setup. Whatever its ‘primary’ monetary policy rule, the central bank is assumed to shift expectations of risk-neutral agents about a default/redenomination of sovereign debts by moving the economy from a ‘bad’ equilibrium, characterized by high expectations of default and an high risk premium, to the ‘good’ equilibrium characterized by low expectations of default and low risk premium. The relevant interest rate that determines the equilibrium in the real economy is made up of two components: a risk-free component plus a risk premium component; hence, the decrease in the risk premium component causes an improvement in real economic activity (see, e.g., Altavilla *et al.* (2017) for the transmission of sovereign spreads to bank lending and funding conditions). Importantly, the shift from the bad to the good equilibrium moves the risk-free components of interest rates upward because the central bank will respond to the improved economic conditions following its primary policy rule.<sup>12</sup>

In the model, the response of the central bank to a contractionary demand shock which triggers the probability of default of peripheral countries induces the following sequence of outcomes: (p1) a decrease in the sovereign risk premium; (p2) an increase of the risk-free interest rate; (p3) an increase of real economic activity. In principle, the outcomes (p1)-(p2)-(p3) might be also ascribed to a ‘pure’ information channel. We solve this lack of ‘theoretical’ identification in the next sections by considering some historical/institutional features that characterize monetary policy in the Euro Area.

## 5 Extracting multiple factors from HF surprises

To identify multiple shocks from HF monetary surprises observed around ECB press conferences we rely on a two-step procedure. In the first-step, we use the EA-MPD HF database of Altavilla *et al.* (2019) to extract a set of orthogonal factors that summarize the dynamics of the Euro

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<sup>12</sup>Similarly, using the lens of a multi-country DSGE model, Darracq Pariès *et al.* (2016) show how the Euro Area economy responds to a shock which increases sovereign risk in peripheral countries (Italy and Spain). Output and inflation decrease and the same occurs to the stock market, while risk-free rates decrease because of the central bank’s commitment to a ‘standard’ monetary policy rule.

Area yield curve, sovereign spreads and the stock market. Combining sign-restrictions with other type of restrictions, we set-identify three factors that approximate the dynamics of HF monetary surprises. Then, we extract three ‘representative’ factors from the so-identified set and use them in a second-step as external instruments (proxies) in a proxy-SVAR estimated on daily data.

In the first-step, the sign-restrictions are informed through the predictions (p1)-(p2)-(p3) of the stylized theoretical model discussed in Section 4 and the other restrictions are narrative-type restrictions that permit to separate the information factor from the spread factor in a set-identification sense. In particular, we rely on two empirical facts: the spread factor tends to cluster around debt crisis periods; the impact of the spread factor on sovereign spreads must be relatively higher (in absolute value) than the impact that the information factor exerts on sovereign spreads.

In the second-step, the objective is to track the responses of financial variables of interest to the three structural shocks, in particular to the spread shock. In this phase, the estimated proxy-SVAR is endowed with additional restrictions necessary to (point-)identify the three structural shocks. We impose a set of restrictions that overidentify the model and permit to separate the spread shock from the information shock. We discuss these restrictions in detail in Section 6.

In this section we focus on the first-step of our procedure. We follow an heuristic process and start from a more ‘conventional’ specification which features two factors only. In line with e.g. Andrade and Ferroni (2021) and Jarocinski and Karadi (2020), we first consider a setup where two factors alone are assumed to drive the movements of the OIS yield curve in the narrow windows around ECB press conferences: a *monetary factor* and a *information factor*, respectively. Doing so, we show that the ‘monetary/information’ paradigm does not fully account for sovereign yield surprises; in particular, the information factor does not capture some comovements of yields and sovereign spreads. Moving one step forward, we show that once sovereign spreads are added to set of relevant HF surprises, the test by Cragg and Donald (1997) (see Table 1) selects an additional, third factor.

In the rest of this section we discuss the two-factors model. We move to the three-factors setup in the next section. Note that in this step we use the term ‘factor’ in place of ‘shock’

because, technically speaking, we consider the problem of extracting factors from Euro Area HF monetary surprises.

$H_0$ : N. of Factors	OIS rates and STOXX50			OIS rates, STOXX50 and IT-OIS spreads			
	Wald Stat.	$\chi^2$ DoF	$p$ -value	Wald Stat.	$\chi^2$ DoF	$p$ -value	
0	91.102	10	0.00000	147.5468	28	0.00000	
1	22.801	5	0.00037	67.0965	20	0.00000	
2	0.8357	1	0.36064	37.9124	13	0.00030	
3				10.9196	7	0.14217	

**Table 1:** Cragg and Donald’s (1997) test for the number of factors. The three columns on the left part of the table show the results for the dataset containing surprises of OIS rates, at maturities 1,2,5 and 10 (years), and the STOXX50 index. The right part refers to the dataset with surprises of OIS rates, the STOXX50 index and IT-OIS spreads, at maturities 2,5 and 10 (years).

**Two-factors model.** Let  $\gamma_t$  be the  $5 \times 1$  vector collecting HF surprises of OIS rates at maturities  $m = 1, 2, 5, 10$  years, respectively, and the STOXX50 index. These surprises are observed around ECB press conferences in the days that cover the period from January 2002 to June 2020. The time index  $t$  denotes days.

Henceforth, with the notation  $\Delta^{hf} w_t$  we indicate the HF variations observed in the time series  $w_t$  in the windows around ECB press conferences; see also footnote 8. The result of Cragg and Donald’s (1997) test in Table 1 (left panel) suggest that the daily dynamics of  $\gamma_t$  can be approximated by the factor model:

$$\gamma_t = \Lambda_{5 \times 2} f_t + e_t \quad , \quad t = 1, \dots, T$$

where  $f_t$  is a  $2 \times 1$  vector of factors,  $\Lambda$  is the  $5 \times 2$  matrix of time-invariant factor loadings and  $e_t$  is a vector of disturbances. The matrix counterpart of the model above is

$$\Gamma_{T \times 5} = F_{T \times 2} \Lambda'_{2 \times 5} + e_{T \times 5}. \quad (1)$$

To set-identify the two factors in  $f_t$  we apply a frequentist sign-restrictions approach. As is known, for any  $2 \times 2$  orthonormal matrix  $Q$  ( $Q'Q = I$ ,  $QQ' = I$ ), the system above can be

rotated and rewritten as:

$$\Gamma = (FQ)(\Lambda Q)' + e = F^*(\Lambda^*)' + e$$

where  $F^*$  and  $\Lambda^*$  are the rotated factors and loadings, respectively. The vector of rotated factors is  $f_t^* = Qf_t$ . We select the rotation matrices  $Q$ s such that the model satisfies the following signs:

$$\begin{pmatrix} \Delta^{hf} OIS_{1y,t} \\ \Delta^{hf} OIS_{2y,t} \\ \Delta^{hf} OIS_{5y,t} \\ \Delta^{hf} OIS_{10y,t} \\ \Delta^{hf} STOXX50_t \end{pmatrix}_{\gamma_t} = \begin{pmatrix} + & + \\ + & + \\ + & + \\ + & \bullet \\ - & + \end{pmatrix}_{\Lambda^*} \begin{pmatrix} f_{mon,t}^* \\ f_{info,t}^* \\ f_t^* \end{pmatrix} + \begin{pmatrix} e_{1,t} \\ e_{2,t} \\ e_{3,t} \\ e_{4,t} \\ e_{5,t} \end{pmatrix}_{e_t} \quad (2)$$

where, henceforth, the two (orthogonal) elements in  $f_t^* = (f_{mon,t}^*, f_{info,t}^*)'$  are interpreted as a monetary factor and an information factor, respectively.

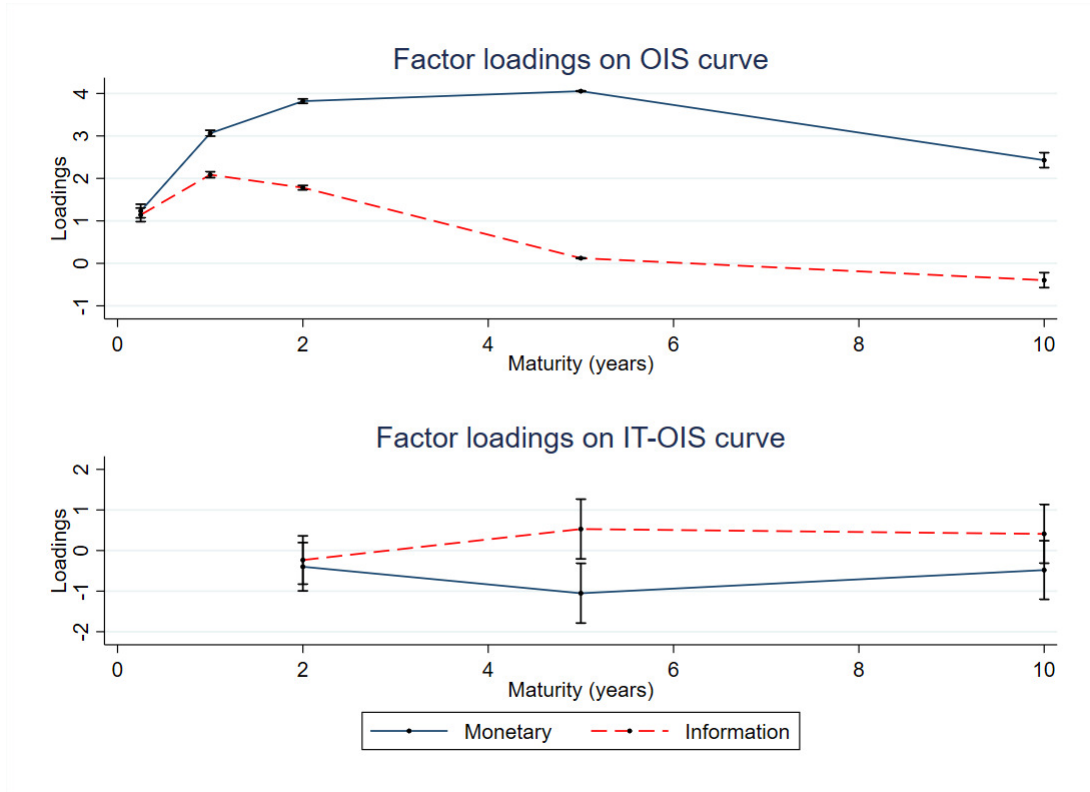
The signs in the specification (2) are borrowed from standard arguments on the monetary/information paradigm. The monetary factor loads positively on the OIS yield curve at all maturities and negatively on the STOXX50 index. Instead, the information factor loads positively both on the OIS yield curve and the STOXX50 index. Driven by the idea that the information revealed by the ECB is unlikely to sharply affect expectations at long horizons, we leave the coefficient that loads the information factor to the 10-year OIS rate unrestricted, which explains the symbol ‘ $\bullet$ ’ in (2). As in Jarocinski and Karadi (2020), and as it can be seen from the last row of the matrix  $\Lambda^*$ , in (2) the information factor is separated from the monetary factor by the sign imposed on the reaction of the stock market index. Note that at this stage we deliberately have not included HF variations of sovereign spreads in the vector  $\gamma_t$ . This choice is motivated by the purpose of analyzing to what extent and in which direction sovereign spreads reacts to the monetary and information factors identified from (2).

The factor model in (2) is estimated by maximum likelihood; see Uhlig (2005).<sup>13</sup> To select two ‘representative factors’ from the identification set obtained from (2), we use Fry

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<sup>13</sup>At each iteration, a  $2 \times 2$  orthonormal matrix  $Q$  is randomly generated and the matrix  $\Lambda^* = \Lambda Q'$  and factors  $F^* = FQ$  are computed. After proper normalization of signs across columns, the validity of the sign restrictions is checked: the generated  $\Lambda^*$  and  $F^*$  that do not respect the signs are discarded, otherwise retained. We repeat the iteration until 1000 valid couples  $(\Lambda^*, F^*)$  are extracted.

and Pagan's (2011) Median Target (MT) method<sup>14</sup> obtaining the (unique) vector of factors  $f_t^{MT} = (f_{mon,t}^{MT}, f_{info,t}^{MT})'$ ,  $t = 1, \dots, T$ . The upper panel of Figure 4 plots the loadings estimated by regressing the HF variations of OIS rates,  $\Delta^{hf} OIS_{my,t}$  at various maturities  $m = 1, 2, 5, 10$  (years), on the factors  $f_t^{MT} = (f_{mon,t}^{MT}, f_{info,t}^{MT})'$ . The graph, which also reports the associated 95%-confidence intervals, shows that, not surprisingly, the information factor loads mainly on the 1-2 years segment of the yield curve, i.e. the horizon at which the information revealed by the ECB is expected to matter most.



**Figure 4:** Estimated monetary and information factor loadings obtained by regressing HF OIS and IT-OIS (Italy) surprises on the two factors. Vertical bars represent 95% confidence intervals.

Now, let  $IT_{my,t}$  be the yield on Italian sovereign bond at maturity  $m$ , and  $\Delta^{hf}(IT_{my,t} - OIS_{my,t})$  the IT-OIS HF spreads, always observed around ECB press conferences. In terms of economic size and dimension of sovereign debt, Italy can be considered the leading representative peripheral country of the Euro Area. The lower panel of Figure 4 plots the loadings estimated

<sup>14</sup>The MT method appears a sensible choice for extracting a representative vector of factors from the identification set. We refer to Fry and Pagan (2011) for a thorough discussion on the merits of the MT method in the sign-restrictions approach.



by regressing the HF variations  $\Delta^{hf}(IT_{my,t} - OIS_{my,t})$ , at maturities  $m = 2, 5, 10$  (years), on the two MT factors, with associated 95%-confidence intervals. It is now seen that the loadings of the monetary factor on the OIS curve are positive (upper panel), while the loadings of the monetary factor on the spread IT-OIS curve are negative. It turns out that the monetary factor generates a negative comovement of OIS rate and IT-OIS spreads which further supports the evidences discussed in Section 3 (see also Appendix A.2). On the contrary, the estimated loadings of the information factor on the IT-OIS spread curve are never significant, i.e. the estimated information factor plays no role in describing HF variations of peripheral spreads around ECB press conferences.

These evidences motivate the tree-factor paradigm discussed next.

**Three-factors model.** We enlarge the information set by augmenting the vector  $\gamma_t$  with the IT-OIS spreads  $\Delta^{hf}(IT_{my,t} - OIS_{my,t})$  at maturities  $m = 2, 5, 10$  (years). The time index  $t$  still represents days. Now the  $8 \times 1$  ‘augmented’ vector,  $\gamma_t^{ag}$ , collects information from both the Euro Area yield curve, Italian yield spreads and the stock market.<sup>15</sup> The estimation sample still covers the period from January 2002 to June 2020.

Cragg and Donald’s (1997) test in Table 1 (right panel) does not reject a third factor, hence the specified (rotated) factor model is now given by

$$\begin{pmatrix} \Delta^{hf} OIS_{1y,t} \\ \Delta^{hf} OIS_{2y,t} \\ \Delta^{hf} OIS_{5y,t} \\ \Delta^{hf} OIS_{10y,t} \\ \Delta^{hf} (IT_{2y,t} - OIS_{2y,t}) \\ \Delta^{hf} (IT_{5y,t} - OIS_{5y,t}) \\ \Delta^{hf} (IT_{10y,t} - OIS_{10y,t}) \\ \Delta^{hf} STOX50_t \end{pmatrix}_{\gamma_t^{ag}} = \begin{pmatrix} + & + & + \\ + & + & + \\ + & + & + \\ + & \bullet & + \\ + & - & -- \\ + & - & -- \\ + & - & -- \\ - & + & + \end{pmatrix}_{\Lambda^*} \begin{pmatrix} f_{mon,t}^* \\ f_{info,t}^* \\ f_{spread,t}^* \\ f_t^* \end{pmatrix} + \begin{pmatrix} e_{1,t} \\ e_{2,t} \\ e_{3,t} \\ e_{4,t} \\ e_{5,t} \\ e_{6,t} \\ e_{7,t} \\ e_{8,t} \end{pmatrix}_{e_t} \quad (3)$$

where  $\Lambda^*$  is, again, the matrix of rotated factor loading and  $f_{spread,t}^*$  is the ‘novel’ spread factor that complements the monetary and information factors  $f_{mon,t}^*$  and  $f_{info,t}^*$  discussed before.

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<sup>15</sup>In the Supplementary Material, Section G, we replace Italian sovereign spreads with Spanish ones. We consider spreads relative to Italy and Spain separately to keep the dimension of the system manageable.

The signs associated with the spread factor in the third column of the matrix  $\Lambda^*$  are partly informed by the predictions (p1)-(p2)-(p3) of the stylized theoretical model sketched in Appendix A.1. It can be noticed that, aside from the symbol ‘—’ whose meaning will be explained below, the signs associated with the rotated factors  $f_{info,t}^*$  and  $f_{spread,t}^*$  are the same in (3). In order to separately identify these two factors, we complement the sign-restrictions with additional narrative restrictions.<sup>16</sup> Let  $D_1 = [2010 - 2014] \cup [2020]$  denote the set including all days in the specified ranges, and let  $1_{D_1}(t)$  be the indicator function being equal to 1 when the day  $t$  belongs to the set  $D_1$  and zero elsewhere. The first condition we use to complement the sign-restrictions in (3) is given by the inequality:

$$Var \left\{ f_{spread,t}^* 1(t \in D_1) \right\} \geq \tau \times Var[f_{spread,t}^* (1 - 1(t \in D_1))] \quad (4)$$

which maintains that the variance of the spread factor is  $\tau > 0$  times larger in the period 2010-2014 (debt crisis) and in 2020 than in the other periods.<sup>17</sup> The condition (4) is justified by the following facts: (i) before 2010 the ECB was not essentially concerned with fragmentation risk and sovereign spreads were not an issue; (ii) since 2010, market pressure on peripheral debt grew considerably culminating in July 2012 with the ‘whatever it takes’ speech by Mario Draghi; (iii) since 2014, peripheral debt has been less exposed to runs and the ECB implemented the APP, i.e. the first QE program which, as explained above, can be ascribed to its unconventional monetary policy rule rather than to the management of fragmentation risk; (iv) with the pandemic outbreak in 2020, the role of the ECB in managing fragmentation risk, acknowledged with the implementation of the PEPP, returns to be once again paramount. The scalar parameter  $\tau$  in (4) is calibrated in the empirical analysis to the value 1.7 which can be given a statistical justification.<sup>18</sup>

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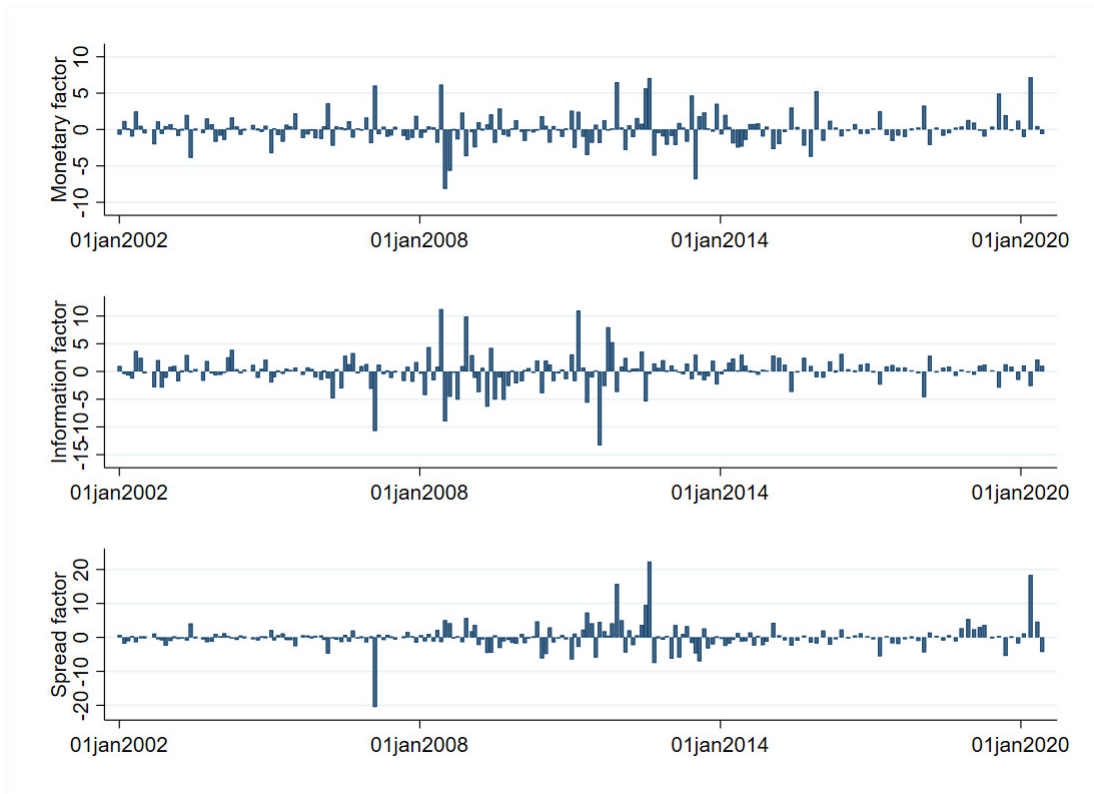
<sup>16</sup>Similar strategies may be found e.g. in Antolín-Díaz and Rubio-Ramírez (2018) and Caggiano *et al.* (2021). Likewise, Swanson (2021) employs ‘variance restrictions’ to identify a QE factor in the US; Furlanetto *et al.* (2019) employ restrictions on the relative magnitude of the response of certain variables in the SVAR to the shocks of interest, as we do for the spread shock; see Ludvigson *et al.* (2021) for a general overview.

<sup>17</sup>Differently from Swanson (2021), we impose the condition (4) in the same way we do for sign restrictions: for each randomly generated matrix  $Q$ , we check whether the condition holds and keep only the rotations that satisfy the restriction.

<sup>18</sup>See Supplementary Material, Section C.

The second condition we impose to complement the sign-restrictions in (3) is that the loadings associated to the spread factor on the IT-OIS spread curve are larger (in absolute value) than the loadings of the information factor on the spread curve. This explains the symbol ‘—’ in (3). This magnitude restriction represents a natural characterization of the spread factor: it must affect sovereign spreads (in terms of magnitude of the impact) more than any other factor extracted from HF surprises.

The factor model in (3) is estimated by maximum likelihood under the sign and the other type of constraints. Henceforth, we denote with  $\mathcal{F}_F$  the set containing 1000 factors  $f_t^* = (f_{mon,t}^*, f_{info,t}^*, f_{spread,t}^*)'$ ,  $t = 1, \dots, T$ , that satisfy the restrictions; furthermore, we denote with  $f_t^{MT} = (f_{mon,t}^{MT}, f_{info,t}^{MT}, f_{spread,t}^{MT})'$ ,  $t = 1, \dots, T$ , three ‘representative’ factors extracted from the set  $\mathcal{F}_F$  using Fry and Pagan’s (2011) MT method. The three representative time series  $f_t^{MT} = (f_{mon,t}^{MT}, f_{info,t}^{MT}, f_{spread,t}^{MT})'$ ,  $t = 1, \dots, T$  are plotted in Figure 5.



**Figure 5:** Estimated monetary, information and spread factors on the period January 2002-June 2020. The monetary and information factors are normalized such that their loading on the 1-year OIS rate is equal to one. The spread factor is normalized such that its loading on the 10-year spread IT-OIS is equal to one. Units on the vertical axis denote basis points.

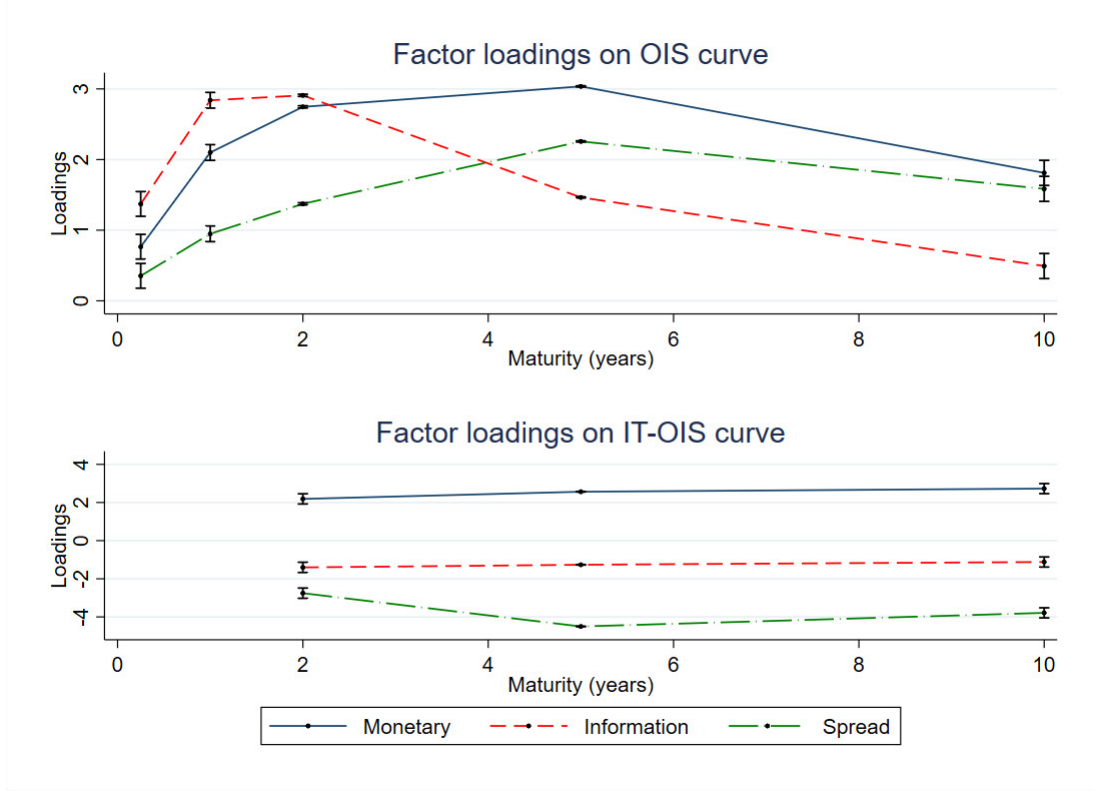
It is seen from Figure 5 that the largest realizations of the MT spread factor, plotted in the graph in the lower panel of Figure 5, are observed in February 2007, December 2011, August 2012 and March 2020, respectively. The last two episodes refer to two important dates associated with the management of the ECB of fragmentation risk. On December 8, 2011, a sharp increase in sovereign spreads is observed, probably reflecting the disappointment of markets that expected the ECB to take active measures to contrast the debt crisis firing up while no measures were actually taken. This episode matches perfectly with our idea of the spread shock. Instead, February 8, 2007, appears an inexplicable ‘outlier’: on that date we observe a sharp increase in medium term OIS rates which our three-factors model explains, quite surprisingly, through a large realizations of the three factors altogether. The graph in the middle panel of Figure 5 plots the MT information factor,  $f_{info,t}^{MT}$ . It shows that one of the ‘biggest’ realizations of this factor takes place in August 2011, a date also identified by Jarocinski and Karadi (2020) as one of the leading examples of the information effect.

The graph in the upper panel of Figure 6 plots the estimated factor loadings obtained by regressing the quantities  $\Delta^{hf} OIS_{my,t}$ ,  $m = 1, 2, 5, 10$  (years) on the three MT factors  $f_{mon,t}^{MT}$ ,  $f_{info,t}^{MT}$  and  $f_{spread,t}^{MT}$ , with associated 95%-confidence intervals. The lower panel plots the loadings estimated by regressing the spreads  $\Delta^{hf}(IT_{my,t} - OIS_{my,t})$ ,  $m = 2, 5, 10$  on the three MT factors, again, with associated 95%-confidence intervals. The graphs show that the information factor is mostly connected to the OIS curve at 1-2 years maturity, while the spread factor at the 5-year maturity. It can be now appreciated that, differently from what documented in Figure 4, the direction through which the monetary factor loads on the OIS and IT-OIS curves is the same, a consequence of the enlargement of the information set and the novel sign restrictions imposed.

Table 2 illustrates how the variability of the components in the vector  $\gamma_t^{ag}$  can be ascribed to each of the three MT factors. Each row of Table 2 is obtained from simple regressions of the form

$$\gamma_{i,t}^{ag} = \lambda_1 f_{mon,t}^{MT} + \lambda_2 f_{info,t}^{MT} + \lambda_3 f_{spread,t}^{MT} + error_{i,t} \quad , \quad t = 1, \dots, T \quad (5)$$

where  $\gamma_{i,t}^{ag}$  is the  $i$ -th component of  $\gamma_t^{ag}$ . The second column in Table 2 sketches the associated  $R^2$ , while the last three columns attribute the overall variability to the three factors through a Shapley  $R^2$  decomposition. The overall  $R^2$  is always high for OIS rates and IT-OIS spread and



**Figure 6:** Estimated monetary, information and spread factor loadings obtained by regressing HF OIS and IT-OIS (Italy) surprises on the three factors. Vertical bars represent 95% confidence intervals.

more modest, not surprisingly, for the stock market index. The contribution of the information factor along the OIS yield curve is extremely variable and declines over maturity. The opposite is true for the spread factor which contributes to the regression variability with a share that increases with maturity.

Figure 7 is based on four relevant dates. The graph plots some HF surprises  $\gamma_{i,t}$  observed in a fixed day  $t = \bar{t}$ , along with the quantities  $\hat{\lambda}_1 f_{mon,\bar{t}}^{MT}$ ,  $\hat{\lambda}_2 f_{info,\bar{t}}^{MT}$  and  $\hat{\lambda}_3 f_{spread,\bar{t}}^{MT}$  predicted by model (5) in the fixed day  $t = \bar{t}$ . August 4, 2011 is interesting for the reasons already mentioned: most of the decrease in the OIS rates, especially at 1-2 years maturity, can be ascribed to the information effect which also drives up the spread IT-OIS. August 2, 2012 refers to the OMT announcement which is followed by the biggest recorded increase in the IT-OIS spread (more than 40 basis points). In fact, financial markets were initially disappointed by the announcement, not fully understanding the implications of the OMT program. In the following days, the trend was reverted and sovereign spreads started to decrease significantly. Nonetheless, this event

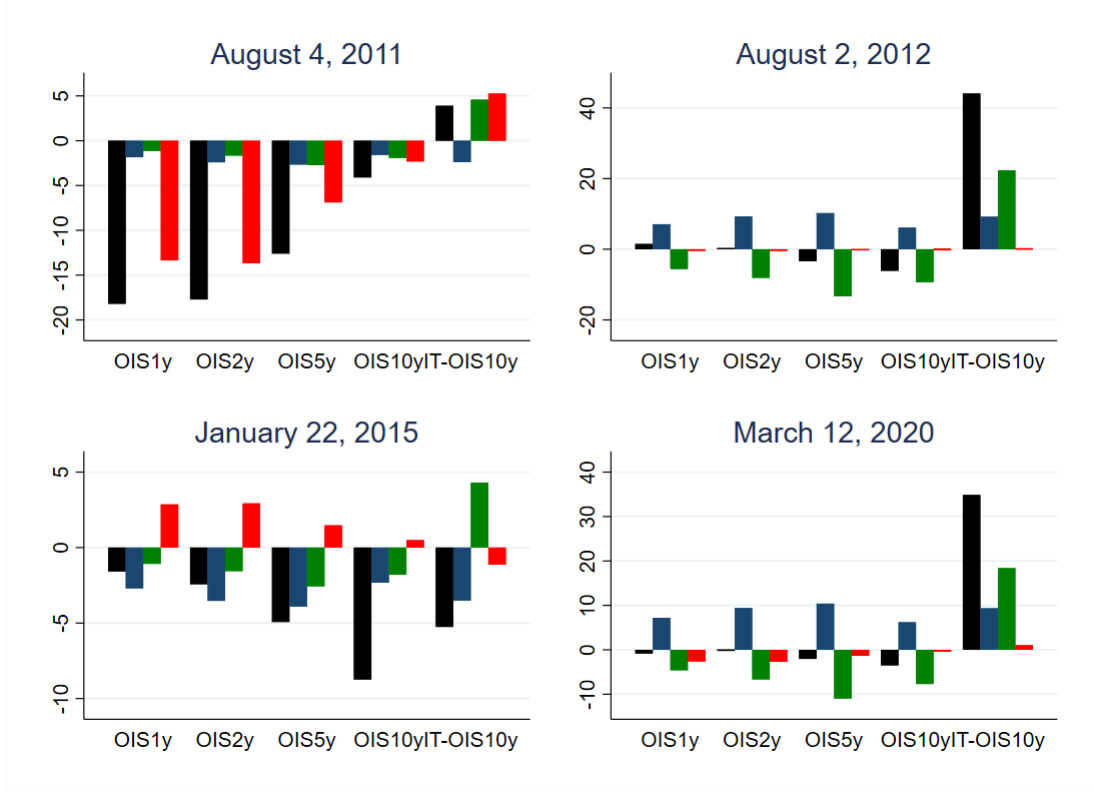
	$R^2$	Monetary factor	Spread factor	Information factor
$\Delta$ OIS 1y	95.6%	33%	6.7%	60.3%
$\Delta$ OIS 2y	99.9%	42.2%	10.5 %	47.3%
$\Delta$ OIS 5y	99.9%	56%	31%	13%
$\Delta$ OIS 10y	79.4%	54.4%	41.6%	4%
$\Delta$ IT-OIS 2y	80%	33.4%	52.9%	13.7%
$\Delta$ IT-OIS 5y	99.9%	23.2%	71.2%	5.6%
$\Delta$ IT-OIS 10y	86.9%	32.3%	62.2%	5.4%
$\Delta$ STOXX50	33.2%	61.7%	32.8%	5.5%

**Table 2:** Percentage of the variance of HF surprises explained by the three factors. The second column summarizes the overall  $R^2$  of the regressions. The other columns report the Shapley  $R^2$  decomposition.

represents a good example of a day characterized by a ‘spread shock effect’. A similar reasoning applies to March 12, 2020. Finally, the date of January 22, 2015 displays variations associated within the day of the QE announcement (the APP). Here the monetary factor drives OIS rates and the IT-OIS spread downward. Nonetheless, a significant spread factor is seen to partially counterbalance the decrease in the IT-OIS spread and further decrease OIS rates. On the same date it is also seen a significant information effect driving OIS rates upward.

## 6 Three shocks identification

In this section we move to the second-step of our empirical identification strategy. Our objective is to jointly (point-)identify the dynamic causal effects produced by the three monetary policy shocks on target variables of interest in a proxy-SVAR based on daily data: the dynamics of stock market prices, the inflation-linked swap rate which reads as a proxy of inflation expectations, and the EUR-USD exchange rate. We use the three MT factors discussed in the previous section as external instruments for three distinct shocks: an unconventional monetary policy shock, and information shock and the spread shock. This second-step allows us to further separate the



**Figure 7:** Black bars denote HF monetary surprises observed at four particular dates ( $\Delta_{i,\bar{t}}^{hf}$ ). Blue, green and red bars correspond to the quantities  $\hat{\lambda}_1 f_{mon,\bar{t}}^{MT}$ ,  $\hat{\lambda}_2 f_{info,\bar{t}}^{MT}$  and  $\hat{\lambda}_3 f_{spread,\bar{t}}^{MT}$  given in equation (5) of the text.

spread shock from the information shock by means of the additional restrictions needed for identification in proxy-SVARs featuring multiple target shocks.

**Proxy-SVAR setup.** We consider the finite-order VAR system:

$$\Pi(L)Y_t = \mu + \delta t + u_t \quad , \quad t = 1, \dots, T \quad (6)$$

where the time index  $t$  represents days,  $Y_t$  is the vector of endogenous variables,  $\Pi(L)$  is a finite-order autoregressive polynomial,  $\mu$  is a constant,  $\delta$  are parameters associated with a linear trend that might characterize some of the variables in  $Y_t$ ; finally,  $u_t$  is the vector of reduced-form innovations assumed with time-invariant covariance matrix,  $\Sigma_u$ . We decompose  $Y_t$  as  $Y_t = (r_t', x_t')'$ , where  $r_t$  contains the so-called ‘policy indicators’, i.e. the variables that can be associated with the target structural shocks and  $x_t$  contains the response variables. The time series included in  $r_t$  and  $x_t$  in the empirical analysis are discussed in detail below. The VAR innovations  $u_t$  can be decomposed likewise  $Y_t$ , i.e.  $u_t = (u_{r,t}', u_{x,t}')'$ .

In a ‘standard’ SVAR context, the reduced form innovations are linked to the structural

shocks by the expression:

$$u_t = C\varepsilon_t \quad (7)$$

where  $\varepsilon_t$  is the vector of (latent) structural shocks and  $C$  is the matrix that collects the instantaneous impact on the structural shocks on the variables. Without loss of generality, we normalize the structural shocks in (7) to have unit variance,  $E(\varepsilon_t \varepsilon_t') = I$ .  $Y_t$  is assumed second-order stationary (up to linear deterministic trends), hence we can consider the corresponding structural vector moving average representation

$$Y_t = \Theta(L)[\mu + \delta t] + \Theta(L)C\varepsilon_t$$

with the polynomial  $\Theta(L) = \Pi(L)^{-1} = I + \Theta_1 L + \Theta_2 L^2 + \dots$  square summable. In addition to (7), we maintain that the spaces spanned by the innovations  $u_t$  and the structural shocks  $\varepsilon_t$  coincide. This condition, implied by the invertibility hypothesis, corresponds to the notion that the structural shocks  $\varepsilon_t$  are fundamental and therefore linearly recoverable from current and lagged values of  $Y_t$ . The invertibility hypothesis will be relaxed in Section 7 when we aggregate the variables from the daily to the monthly frequency.

The objective of our analysis is the identification of a subsets of the structural shocks in  $\varepsilon_t$ , say  $\varepsilon_{r,t}$ . Given the decomposition  $\varepsilon_t = (\varepsilon'_{r,t}, \varepsilon'_{x,t})'$ , the relation in (7) is restated as

$$u_t = C_r \varepsilon_{r,t} + C_x \varepsilon_{x,t} \quad (8)$$

where it is seen that the matrix  $C_r$  collects the on-impact responses of the variables to the target structural shocks,  $\varepsilon_{r,t}$ . The (population) impulse response functions of interest are given by the expression

$$\frac{\partial Y_{t+h}}{\partial \varepsilon_{r,t}} = (SA^h S')C_r \quad , \quad h = 1, \dots, h_{\max} \quad (9)$$

where  $A$  is the VAR companion matrix,  $S$  is a selection matrix and  $h_{\max}$  is the maximum time (day) horizon considered. The parameters in  $C_r$ , jointly with the reduced form VAR dynamics in  $\Pi(L)$  (compacted in the companion matrix  $A$ ), provide the dynamic causal effects produced by the structural shocks in  $\varepsilon_{r,t}$ . In proxy-SVARs, the ‘partial identification’ problem that arises from the estimation of the impulse response functions in (9) is solved by employing variables  $Z_t$  external to the VAR system which are correlated to the structural shocks  $\varepsilon_{r,t}$  (relevance conditions) and uncorrelated with the structural shocks in  $\varepsilon_{x,t}$ , not of interest (exogeneity condition).



Let  $k$  be the number of structural shocks in  $\varepsilon_{r,t}$ . In our leading specification,  $\varepsilon_{r,t}$  is a three-dimensional ( $k = 3$ ) vector that collects the monetary policy shock, the information shock and the spread shock, respectively.<sup>19</sup> Let  $Z_t$  be the  $k \times 1$  vector of external variables (proxies) that satisfy the relevance and exogeneity conditions

$$E(Z_t \varepsilon'_{r,t}) = \phi, \quad \text{rank}[\phi] = k, \quad E(Z_t \varepsilon'_{x,t}) = 0.$$

We can conveniently summarize these conditions in the linear measurement error model

$$Z_t = \phi \varepsilon_{r,t} + \sigma_\omega \omega_t \tag{10}$$

where  $\omega_t$  is a zero-mean measurement error with unit covariance matrix, is assumed uncorrelated to the structural shocks of the system, and  $\sigma_\omega$  is a positive definite symmetric matrix such that  $\sigma_\omega \sigma'_\omega$  is the covariance matrix of the measurement error term.

**Estimation challenges and solutions.** Two main challenges characterize the estimation of the proxy-SVAR introduced above. First, it is necessary to select a  $k \times 1$  vector of proxies  $Z_t$  from the set of potentially admissible factors  $\mathcal{F}_F$ . Second, given the multiple shocks setup ( $\varepsilon_{r,t}$  contains  $k = 3 > 1$  structural shocks), it is necessary to impose additional restrictions on the model parameters other than the instruments to (point-)identify the impulse response functions in (9). Mertens and Ravn (2013) and Angelini and Fanelli (2019) have shown that at least  $\frac{1}{2}k(k-1)$  additional restrictions are needed on the elements of the matrix  $(C_r, \phi)$  for identification.

We solve the first issue by considering the vector of MT factors  $Z_t = f_t^{MT} = (f_{mon,t}^{MT}, f_{info,t}^{MT}, f_{spread,t}^{MT})'$  plotted in Figure 5 as ‘natural’ external instruments for the three structural shocks. We solve the second issue by estimating the proxy-SVAR by imposing 4 restrictions on the parameters in  $(C_r, \phi)$ , one more than the  $\frac{1}{2}k(k-1) = 3$  restrictions necessary for exact identification. The advantage in this case is that we can test the validity of the proxy-SVAR by testing the overidentification restrictions. In a nutshell, we posit a triangular structure for the matrix of relevance parameters  $\phi$ , which implies 3 restrictions, and one additional zero restriction on the matrix of on-impact coefficients  $C_r$ . The latter allows us to fully isolate the spread shock from the information shock and is explained in detail below.

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<sup>19</sup>For comparative purposes, in the Supplementary Material, Section D, we also consider the ‘two-shocks’ setup where  $\varepsilon_{r,t}$  is  $2 \times 1$  and collects the monetary policy shock and the information shock.

$Corr(f_{mon,t}^{MT}, \hat{\varepsilon}_{mon,t})$	$Corr(f_{info,t}^{MT}, \hat{\varepsilon}_{info,t})$	$Corr(f_{spread,t}^{MT}, \hat{\varepsilon}_{spread,t})$
24.5%	18.5%	18.8%
[14.2, 27.8 ]	[11.4, 25.1]	[14.1 , 24.8 ]

**Table 3:** Estimated correlations between the external instruments and the identified structural shocks recovered through the CMD estimation approach. 90% confidence intervals in brackets.

The estimation of the so-specified proxy-SVAR is based on the classical minimum distance (CMD) estimation approach developed in Angelini and Fanelli (2019).<sup>20</sup> This provides (point-)estimates of the impulse responses in (9) and a statistical test of the validity of the overidentification restriction embedded in the model. Finally, we quantify the statistical uncertainty surrounding the dynamic causal effects produced by the three shocks by the moving block bootstrap (MBB) method extended by Jentsch and Lunsford (2021) and Jentsch and Lunsford (2019) to the proxy-SVARs setup.

**Empirical specification and results.** In the ‘three-shocks’ specification,  $Y_t = (r'_t, x'_t)'$  is  $6 \times 1$ . The vector of policy indicators  $r_t$  is  $3 \times 1$  and contains the following variables: the 5-year and the 1-year sovereign AAA-rated yields constructed by the ECB by averaging yields from Euro Area sovereign rates with triple A rating, and the 10-year spread IT-OIS. The vector of response variables,  $x_t$ , contains: the log of the STOXX50 index; the 2-year inflation-linked swap rate as a proxy of inflation expectations; the log of the EURO-USD exchange rate. These variables are similar to those used in Altavilla *et al.* (2019).

As observed above, the matrix of relevance parameters  $\phi$  is specified upper triangular, a condition which provides 3 restrictions necessary to (point-)identify the three structural shocks. Given the instruments  $Z_t \equiv f_t^{MT} = (f_{mon,t}^{MT}, f_{info,t}^{MT}, f_{spread,t}^{MT})'$  and the linear measurement error model in (10), the upper triangular form of  $\phi$  implies that the monetary factor may potentially convey information on all three structural shocks (up to measurement error), the information factor conveys information on the spread shock other than the information shock (up to measure-

<sup>20</sup>Details on the estimation approach are discussed in the Supplementary Material, Section B1.

ment error) and, finally, the spread factor only instruments the spread shock (up to measurement error). The fourth point restriction is a zero restriction on the matrix of on-impact coefficients  $C_r$  and amounts to assuming that the 2-year inflation-linked swap rate does not respond on impact (within the day) to the spread shock. The argument is as follows. The information channel is motivated by the idea that the central bank reveals information about the future economic outlook affecting expectations. The inflation rate is a key target variable for the ECB, hence it is difficult to conceive an information shock that does not affect inflation expectations on-impact. On the contrary, it is reasonable to assume that it may take at least one day for the market to fully gauge the effects of the spread shock on inflation and thus adapt its expectations. With this additional restriction we strengthen the identification by ensuring that the spread shock is purged from ‘pure’ information channel components. This hypothesis is tested against the data through the overidentification restriction test commented below.

The proxy-SVAR is estimated on the period 15-08-2005–30-06-2020.<sup>21</sup> The reduced form system (6) includes six lags (selected by minimizing the AIC criterion), a constant and a deterministic linear trend.

Before presenting the estimated impulse responses, we briefly investigate the strength of the proxies through measures of ‘statistical reliability’ similar to those produced in Mertens and Ravn (2013) and then discuss the test for the overidentification restriction. Table 3 summarizes the estimated correlations between the instruments  $Z_t \equiv f_t^{MT} = (f_{mon,t}^{MT}, f_{info,t}^{MT}, f_{spread,t}^{MT})'$  and the structural shocks recovered by the CMD approach. Each instrument appears sufficiently correlated with the respective structural shock in the sense that the lower bounds of 90% confidence intervals do not reach ‘pathological’ low levels: the lowest 90% lower bound is that for the correlations between the information factor and the information shock and is around 12%, as opposed to the upper bound, equal to 24%. Considering the daily data setup, the quality of the identification resulting from Table 3 appears sufficient to proceed with standard asymptotic methods of inference. The bootstrap version of the test for the overidentification restriction that characterizes the parameters  $(C_r, \phi)$  of the proxy-SVAR has p-value 0.49, hence the three shocks-based proxy-SVAR is not rejected by the data. Table 4 summarizes the CMD estimates

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<sup>21</sup>OIS rates at long maturities are not available before the date of 15-08-2005.

	Shocks		
	Monetary	Information	Spread
Estimate of $C_r$			
5Y AAA rate	<b>-0.1000</b>	-0.0220	<b>0.0297</b>
1Y AAA rate	<b>-0.0546</b>	<b>-0.1000</b>	<b>0.0137</b>
10Y spread IT-OIS	-0.1496	0.0040	<b>-0.1000</b>
STOXX50	<b>0.0291</b>	-0.0080	<b>0.0108</b>
2Y-ILS	0.0209	<b>-0.0309</b>	0
EUR-USD	<b>-0.0091</b>	-0.0003	<b>0.0046</b>
Estimate of $\phi$			
Monetary factor	<b>0.0530</b>	-0.0130	-0.0002
Information factor	0	<b>0.0404</b>	<b>0.0175</b>
Spread factor	0	0	<b>0.0421</b>

**Table 4:** CMD estimates of the structural parameters in  $C_r$  and  $\phi$  of the overidentified proxy-SVAR. Bold numbers denote estimated parameters whose associated 90%-MBB confidence intervals do not contain the zero.

of the proxy-SVAR parameters  $(C_r, \phi)$ , with coefficients significant at the 90% confidence level in bold.

The impulse response functions are plotted in the columns (a), (b) and (c) of Figure 8 over an horizon of 1000 days (corresponding to roughly three years), along with 68%- and 90%-MBB confidence intervals. The three shocks are normalized to lower their respective policy indicators by 10 basis points. For comparative purposes, the columns (d) and (e) in Figure 8 also plot the impulse response functions obtained when the proxy-SVAR is estimated by considering two-shocks only, i.e. without including the spread shock into the picture (see Section D in the Supplementary Material for details).

We emphasize in Figure 8 the effect that the monetary shock exerts on the risk premium on Italian bonds. This shock has been normalized to reduce the 5-year risk-free rate by 10 basis points on-impact, hence it reads as an expansionary monetary policy shock. We observe

a strong pass-through to the Italian risk premium, a result which is not observed in the two-shocks model, where a decrease in the risk-free rate leads to a slight increase in the periphery risk premium. The negative response of the IT-OIS spread is sizeable (25 basis points at the peak) and persistent. The EUR-USD exchange rate depreciates in both specifications; inflation expectations slightly increase in the short term when considering 68%-confidence bands. This finding is at odds with results from the two-shocks scenario where no significant reaction is detected.

The information shock is normalized in Figure 8 to lower the 1-year risk-free yield by 10 basis points, hence it can be regarded as a ‘contractionary’ one in the sense that one expects a worsening of agents’ expectations about future economic outlook in response to it. The 5-year rate response decreases as well, but the effect is much weaker (5 basis points peak decrease). The information shock increases the Italian risk premium though the effect is not statistically significant. In line with the mechanics of a signalling channel, inflation expectations react significantly only to the information shock: we estimate a 5 basis points peak decrease.

Finally, the spread shock is normalized in Figure 8 to lower the spread IT-OIS by 10 basis points. The estimated response remarks a persistent and significant reduction which lasts about 200 days. Furthermore, risk-free yields increase in response to the spread shock. The increase is modest but significant: approximately 2 basis points for the 1-year yield, and 3-basis points for the 5-year yield. The larger increase observed in the 5-year yield suggests that the expansionary spread shock makes the risk-free yield curve steeper. The increase in risk-free rates is quite persistent and lasts roughly 200 days. The expansionary spread shock is also accompanied by an increase in stock market prices and an appreciation of the EUR-USD nominal exchange rate. Overall, the dynamic causal effects estimated for the spread shock do not appear at odds neither with the predictions of the stylized theoretical model considered in Section 4 (and Appendix A.1), nor with the results in Motto and Özen (2022), see Section 2 for details. Overall, these responses are new in the literature and quantify the role the ECB plays in managing fragmentation risk.

Figure 8 also suggests that the central bank’s concern for fragmentation risk is beneficial in a deflationary environment for the private banks of ‘core’ Euro Area countries. Profits of private banks strongly depend on long term risk free yields which, albeit permanently set at very low

(even negative) levels, are moved upward by policies that reduce fragmentation risk through expansionary spread shocks. Similarly, in an inflationary environment where the central banks undertakes a contractionary policy cycle, reducing fragmentation risk helps to further push the OIS yield curve upward.

## 7 The impact of the spread shock on monthly data

In this section we analyze the dynamic causal effects produced by the spread shock on target variables available at the monthly frequency, relevant for the Euro Area business cycle. The idea is to analyze to what extent the responses of variables like industrial production, prices and measures of systemic risk and financial distress to the identified spread shock conform to the predictions of the stylized model discussed in Section 4 (see also Appendix A.1).

Moving from daily to monthly data requires aggregating some of the daily variables used in the previous section. Aggregation through averaging may cause possible losses of information and non-invertibility issues that we face empirically as follows.<sup>22</sup> Differently from Gertler and Karadi (2015), Alessandri *et al.* (2021) and Motto and Özen (2022), we quantify the dynamic causal effects produced by the spread shock by LP-IVs à la Stock and Watson (2018). The advantage of this approach stands in its robustness against the possible non-invertibility of the spread shock and the potential diminished strength of the instrument used to identify it.<sup>23</sup>

The available estimation sample covers the period 2002M1-2020M6. The response variables we consider in the LP-IVs are: (i) the 5-year and (ii) the 1-year sovereign AAA-rated Euro Area average yields; (iii) the 10-year spread IT-OIS; (iv) the log of the STOXX50 index; (v) the log of the Euro Area industrial production index (excluding construction); (vi) the log of the HICP index; (vii) the CISS index of systemic risk and financial distress directly produced by the ECB. All variables, originally available at the daily frequency are aggregated to the monthly frequency

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<sup>22</sup>As argued in Forni and Marcellino (2016) and Forni *et al.* (2019), estimating a low-frequency structural time series model obtained by aggregating data stemming from an higher frequency data generating process may create important problems for identification. Alessandri *et al.* (2021) rationalize the practice of using daily data to identify structural shocks and then averaging them in estimation exercises carried out at the monthly frequency.

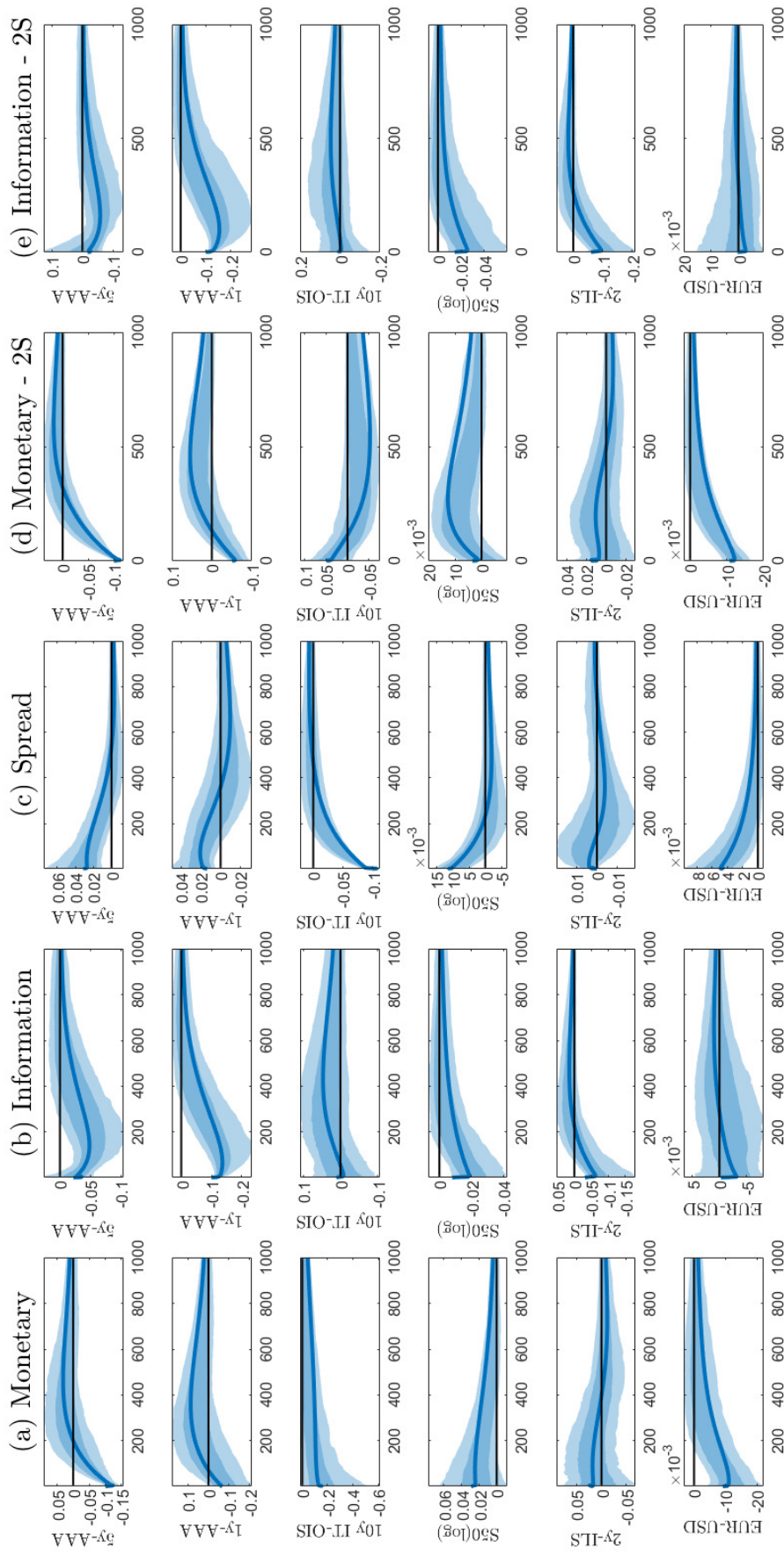
<sup>23</sup>We discuss the econometric details of our identification-robust LP-IVs approach in Section B2 of the Supplementary Material.

by averaging.

The computed effective first-stage F-statistic associated with the local projection estimated at the horizon  $h = 0$  is equal to 10.6, a value that supports our identification-robust approach.

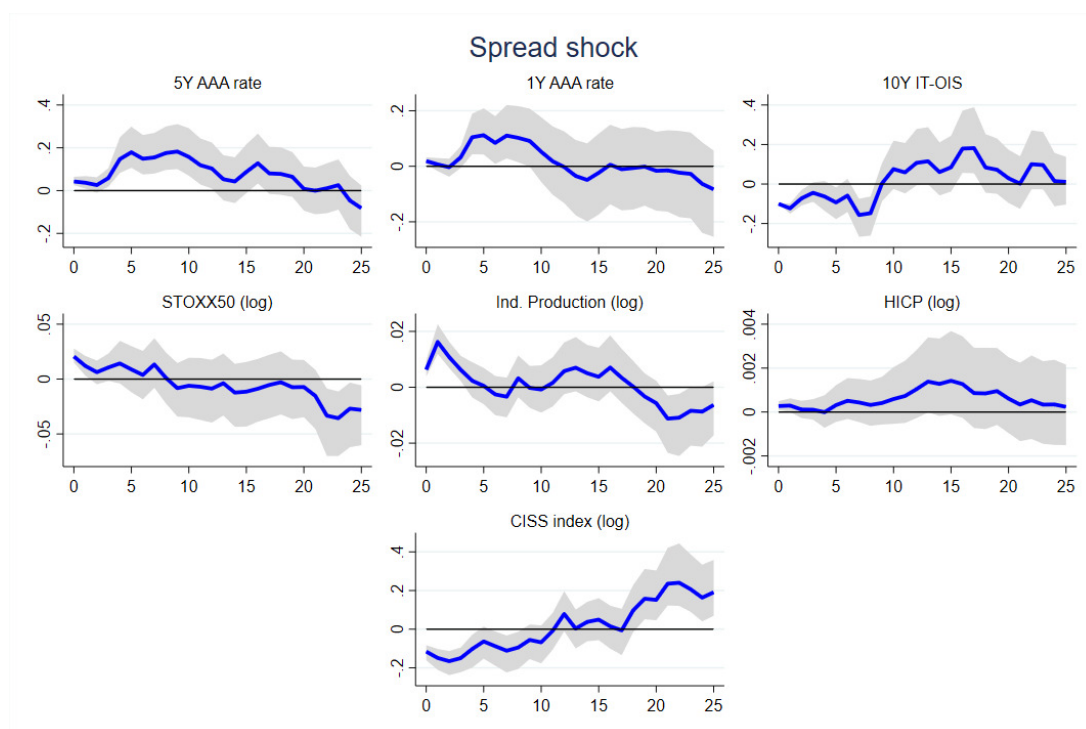
Figure 9 plots the estimated impulse responses over an horizon of  $h_{\max} = 25$  months with associated 68%-AR confidence intervals. It can be noticed that the negative response of the 10-year spread IT-OIS to the spread shock is significant and lasts almost one year. This decline is accompanied by an increase in both the 1-year and 5-year risk-free rates. The increase is more pronounced and persistent for the 5-year rate. Also the STOXX50 index responds positively on-impact. Industrial production increases significantly in the first three-four months. Consumer prices display a lagged and weak positive response. Furthermore, we observe a strong reduction in systemic stress as measured by the CISS index that seems to persist almost one year after the shock.

Overall, the identification-robust local projection analysis conforms to what the dynamic causal effects produced by a ‘spread shock’ should look like according to the stylized paradigm outlined in Section 4 and in Appendix A.1: the reduction in the Italian sovereign spread due to the spread shock is expansionary as stock prices and industrial production tend to increase (the effect is less clear-cut for prices), and induces an increase in the risk-free yield curve. The strong reaction of the CISS index is particularly consistent with our stylized model as the CISS index is built on several forward-looking measures that capture agents’ expectations, and the spread shock is ultimately an expectations-driven object.



**Figure 8:** Impulse responses to the three monetary policy shocks estimated by the daily proxy-SVAR. Shaded areas correspond to 90%-MBB confidence intervals, darker areas to 68%-confidence intervals.





**Figure 9:** Responses to the spread shock obtained from LP-IVs (see Supplementary Material, Section B.2, for details), on monthly data. Shaded areas correspond to 68%-AR confidence sets. Estimation period: 2002M1-2020M6.

## 8 Conclusions

The conduct of monetary policy in the Euro Area is complicated by the fact that there are 19 sovereign bond markets which make fragmentation risk a concern for policy makers. The years of the sovereign debt crisis and the recent global crisis due to the Covid-19 pandemic have emphasized the crucial role that the ECB plays in stabilizing economic activity by unconventional tools which include, among others, ‘monitoring’ sovereign spreads. In this paper we have developed the idea that HF monetary surprises in the Euro Area also reflect the role the ECB plays in managing fragmentation risk.

Using a novel methodology which combines different identification schemes, we have (point-)identified a novel spread shock complementary to the monetary and information shocks. The spread shock reflects policies/announcements by the ECB that reduce pressures on the risk premia on peripheral countries. Empirical results based on daily and monthly data on the period 2002-2020 suggest that the spread shock produces effects on financial and macroeconomic variables that align with the predictions of a simple, stylized model where a central bank in a monetary union acts to offset self-fulfilling expectations of sovereign defaults. Importantly, the spread shock complements, not substitutes, the information shock.

Our evidence that the spread shock is a key ingredient of the monetary policy transmission mechanism in the Euro Area is further strengthened by the decision of the ECB to launch a new program of bond purchases, the Transmission Protection Instrument (TPI), in Summer 2022. The TPI has been specifically designed to address fragmentation risk under the announced tightening cycle of monetary policy in response to cost-driven inflationary pressures. Seen through the lens of our three-shocks decomposition, the need for a ‘separate’ anti-fragmentation policy appears a ‘natural’ course of action for a central bank in the Euro Area. In a deflationary environment, a single expansionary measure (e.g. the PEPP), can simultaneously address the risk of deflation and of rising sovereign spreads. On the contrary, in a cost-driven inflationary environment, one needs a combination of a contractionary monetary shock and an expansionary spread shock in order to control simultaneously inflation and fragmentation risk.

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## A A stylized theoretical model and further empirical evidence

In this Appendix we rationalize the mechanism behind the *spread shock* and provide additional empirical evidence other than in Section 3.

### A.1 Model

The model builds on a slightly modified version of the multiple equilibria model considered in De Grauwe and Ji (2013). A sovereign country in a monetary union faces a choice of whether defaulting or not on its outstanding debt. Defaulting on sovereign debt provides some benefit to the government, which is no longer forced to collect taxes to fund interest expenses and repay the existing debt. We assume that this benefit,  $B$ , is a negative function of the real economic activity level,  $y$ . When  $y$  is low, tax revenues are low and the public budget deteriorates. This increases the outstanding debt and makes it even harder to collect more taxes to pay for interest expenses. One consequence is that the benefit of default increases. The cost of default is fixed and equal to  $C$ . We further assume that when the benefit of default exceeds the cost, the government defaults with probability  $p$ , a monotone function of the net benefit from default. Formally:

$$p(B - C) = \begin{cases} p \in (0; 1] & \text{if } B - C > 0 \\ 0 & \text{if } B - C \leq 0 \end{cases} \quad (11)$$

with  $\frac{\partial p}{\partial (B-C)} > 0$  and  $\lim_{(B-C) \rightarrow \infty} p = 1$ .

We consider two possible scenarios. In the first scenario, denoted *scenario E*, the default is expected by the investors with probability  $p$  as given in (11). In the second scenario, denoted *scenario U*, the sovereign default is always unexpected and does not occur. The central bank may shift expectations about a default/redenomination of sovereign debt by moving the economy from the ‘bad’ equilibrium E, characterized by high risk premium and high expectations of default, to the ‘good’ equilibrium U, characterized by low risk premium and low expectations of default.

In the *scenario E*, the probability of default given in (11) is priced in sovereign bonds, which will carry a positive risk premium that tend to infinity as the net benefit of default increases. Assuming that investors are risk-neutral, a no-arbitrage condition implies that the risk premium is given by  $x = \frac{p}{1-p}(1 + r)$ , a convex and increasing function of  $p$ , with  $r$  risk-free component.



This scenario corresponds to the red lines plotted in the two graphs in Figure 10. In the bottom graph, the benefit of default, denoted  $B_E$ , is plotted as a function of real activity,  $y$ . As  $y$  decreases, the benefit of default increases. Let  $i$  be the nominal interest rate, made up by the risk-free component,  $r$ , and the risk premium component,  $x$ . The top graph maps possible equilibria in the  $(y, i)$ -space that characterizes a simplified ‘textbook-style’ IS-LM representation. Equilibrium is defined by a negatively sloped  $IS$  curve and a positively sloped  $LM$  curve, where the latter approximates the central bank’s reaction function. In this scenario, the relevant  $LM$  curve is  $LM_E$  and incorporates the risk premium induced by investors’ expectations.

In the *scenario U*, the sovereign default is always unexpected. This translates in a different benefit function  $B_U$  which, as detailed in De Grauwe and Ji (2013), stands always ‘below’ the curve  $B_E$ . The rationale is that when the default is expected with some positive probability, the risk premium increases making the cost of servicing the debt higher. This creates an additional incentive to default relative to the unexpected default scenario in which the risk premium is always equal to zero. The  $LM$  curve is  $LM_U$ , with the risk premium  $x$  being zero for levels of economic activity such that the  $B_U$  curve stands below the line  $C$ .

Assume the economy is in the equilibrium  $(y_1, i_1)$ . Here  $B_U < B_E < C$ , so default does not occur. The risk premium is zero, hence  $x_1 = 0$  and  $i_1 = r_1$ . Assume now that a contractionary demand shock shifts the  $IS$  curve on the left in the position  $IS'$  in the graph. In the expected default *scenario E*, the equilibrium will move to  $(y_2, i_2)$ . Here we have  $B_E > C > B_U$ , i.e. the benefits of default exceeds the cost. According to (11), a positive probability of default, say  $p_2 > 0$ , occurs, and this translates into a positive risk premium  $x_2 = \frac{p_2}{1-p_2}(1 + r_2)$ , which contributes to the new equilibrium level of the interest rate,  $i_2 = r_2 + x_2$ . Assume the central bank operates to shift expectations about the probability of default from the *scenario E* to the *scenario U*. For all output levels for which  $B_E > C$ , the central bank acts to shift the benefit curve from  $B_E$  to  $B_U$ . If it succeeds, the risk premium shifts to zero ( $x_3 = 0$ ) and since the relevant  $LM$  curve to consider is  $LM_U$ , the economy will reach the new equilibrium  $(y_3, i_3)$ , where  $B_U < C$ . Default does not occur because of (11). At the new equilibrium, the interest rate is equal to  $i_3 = r_3$  where, recall,  $x_3 = 0$ .

Multiple equilibria can occur in this stylized model only in the region of the graph in which

the  $B_U$  curve lies below the line  $C$  and the  $B_E$  curve lies above the line  $C$ . Indeed, only in this region the unexpected default *scenario*  $U$  leads to a second equilibrium characterized by zero probability of default. Conversely, for  $B_U > C$  (see the left part of the graph), zero probability of default cannot be an equilibrium. In other words, in the far-left part of the graph, the central bank loses its capability to affect expectations and the risk premium.

The crucial hypothesis behind the mechanism outlined in this stylized model is that the central bank can affect expectations about sovereign default generating a mechanism that we conventionally label with *spread shock*. The central bank's response to a contractionary demand shock which triggers the probability of default of peripheral countries generates by the following sequence of outcomes: (p1) a decrease in the risk premium from  $x_2 > 0$  to  $x_3 = 0$ ; (p2) an increase of the risk-free interest rate from  $r_2$  to  $r_3$ ; (p3) an increase of real economic activity from  $y_2$  to  $y_3$ .<sup>24</sup> An unconventional monetary policy shock does not typically account for the sequence (p1)-(p2)-(p3) while, on the contrary, an information shock potentially does.

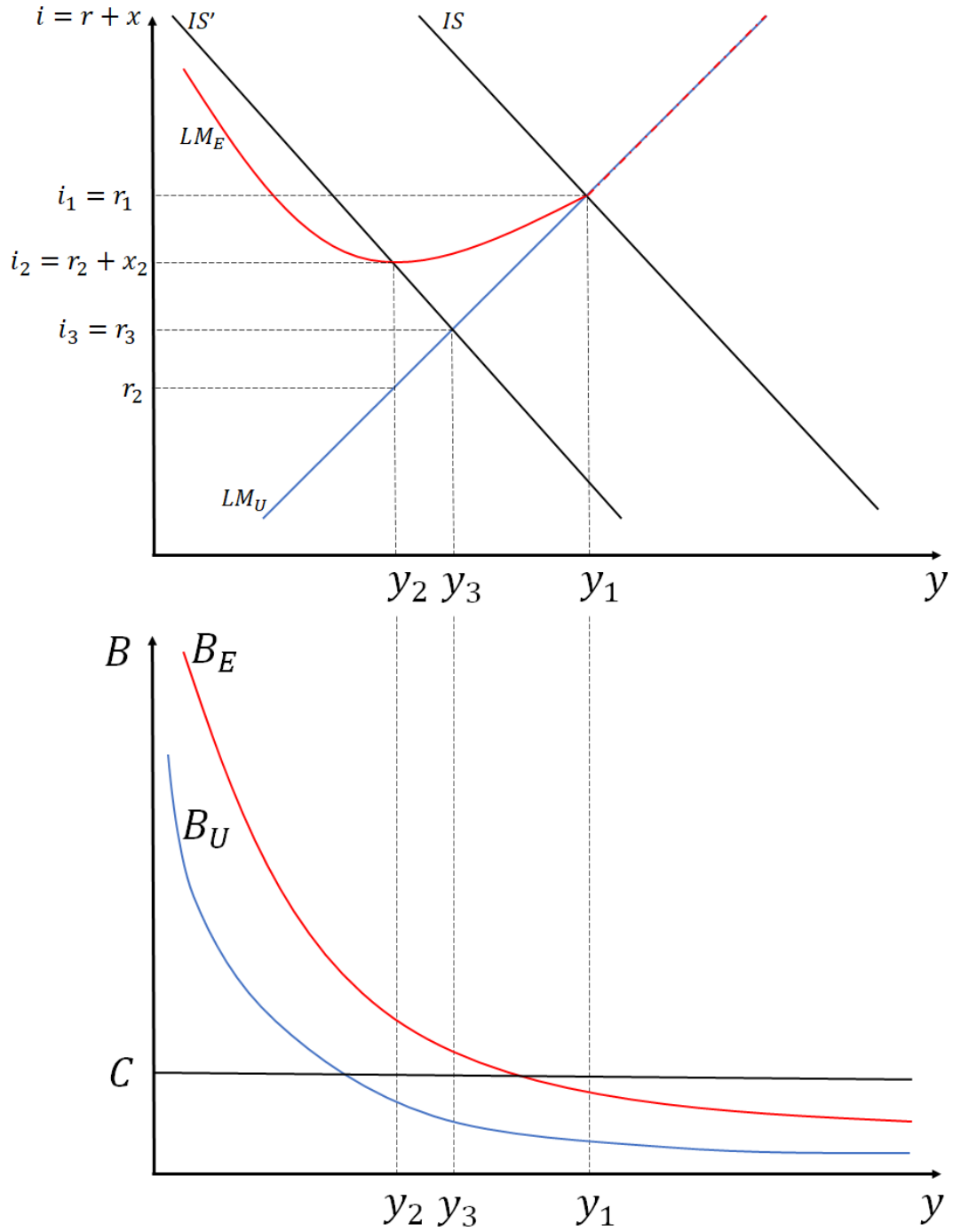
## A.2 Further empirical evidence

The novelty of our approach resides in the acknowledgment that a spread shock, which lowers expectations about default(s) and hence sovereign risk premia, should be accompanied by an increase in the risk-free rates. This explains some of the puzzling comovements outlined in Section 3. A close inspection of some relevant ECB press conferences helps to confirm our 'spread shock' hypothesis.

On September 6, 2012, the details of the OMT were announced. The OMT is largely recognized as being one of the most effective measures taken to shift expectations on sovereign defaults downwards, even though the funding line under the program has been never activated. In the ECB press conference held on September 6, 2012, we observe a large reduction in the risk premium on Italian bonds associated with an increase in long term OIS risk free rate; this is seen in the first row of Table 5. The actual OMT announcement took place on August 2,

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<sup>24</sup>The effects on stock prices of moving from one equilibrium to the other could be mixed in theory, as the increase in prices due to the increase in real economic activity  $y$  can be counter-balanced by the increase in the discount rate  $r$ . We refer to Cieslak and Schrimpf (2019) for a comprehensive discussion on how non-monetary shocks can affect stock prices. As they point out, the positive effect induced by the increase in  $y$  should prevail.



**Figure 10:** A stylized model of multiple equilibria.

2012. This date represents a quite peculiar case because the OMT announcement was initially interpreted as a decision that the ECB was not willing to fully protect exposed countries. This explains why one can observe a steep increase in the risk premium. This initial reaction was then counterbalanced in the subsequent days. What is interesting for us, though, is that this

‘restrictive’ spread shock, is linked to a decrease in the OIS rate, as expected (see Table 5). ‘Il Sole 24 ore’, the main Italian financial newspaper, commented market reactions on August 3, 2012, by writing (our translation): ‘*In the current situation, with high spreads and highly fragmented markets, the effects of monetary policy do not transmit to the whole Eurozone.*’ In other words, the easing monetary policy, measured by the reduction in OIS rates, did not spill over to the Italian risk premium. The interpretation we provide in this paper goes the other way round: the restrictive spread shock, measured by the increase in the Italian risk premium, spilled over to OIS rates, reducing them. Another emblematic example is July 26, 2012, the day of the famous ‘*whatever it takes*’ speech by Mario Draghi. In that day we observe a large decrease in the periphery spreads, while the 10-year OIS rate increased, as expected, in response to a spread-driven monetary policy shock. Finally, consider the date of January 22, 2015, when the APP was announced: we observe a similar reaction of the 10-year OIS rate and the 10-year IT-OIS spread (see Table 5). This fact appears consistent with the idea that an expansionary unconventional monetary policy like the QE reduces risk premia.

Summing up, we expect to observe a positive comovement of long term OIS rate and the peripheral risk premium when a *monetary shock* is occurring and a negative comovement when the *spread shock* is instead at work.

Episode	10-year OIS surprise	10-year spread IT-OIS surprise
6 <sup>th</sup> September 2012: OMT announcement	0.12	-8.87
2 <sup>nd</sup> August 2012: OMT announcement	-6.09	38
22 <sup>th</sup> January 2015: QE announcement	-8.74	-14

**Table 5:** Monetary surprises around ECB conferences in the 10-year OIS rate and in the 10-year spread IT-OIS in three relevant dates. Variations in basis points.